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ENVIRONMENTAL OUTLOOK 1980

OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

FOREWORD

the

A number of recent actions have been taken to ensure that our research program better supports regulatory activities and better prepares the Agency to deal with future environmental problems. One of these actions was to establish an Office of Strategic Assessment and Special Studies in the Office of Research and Development. Environmental Outlook 1980 is the first major report produced by this office. While in many respects more a blueprint for future reports than a comprehensive assessment of future environmental trends, this 1980 report marks progress toward achieving our objective of providing participants in ~~our~~ long-range research and development planning process an overview of likely environmental futures and an interpretation and analysis of potentially significant future environmental problems.

The Office of Strategic Assessment and Special Studies is already taking steps to improve future Environmental Oulook reports. We welcome comments and suggestions concerning how to improve future reports and make them more useful.

Stephen J. Gage

Stephen J. Gage
Assistant Administrator for
Research and Development

PREFACE AND ACKNOWLEDGMENTS

Environmental Outlook is an annual publication of the Office of Research and Development (ORD), U.S. Environmental Protection Agency (EPA). Under the direction of Irvin L. (Jack) White, this report for 1980 has been produced by an interdisciplinary team whose members were drawn from ORD's Office of Strategic Assessment and Special Studies and four contractors: The MITRE Corporation/Metrek Division (prime contractor), CONSAD Research Corporation, International Research & Technology Corporation, and Urban Systems Research and Engineering, Inc. The Control Data Corporation provided computer services support for the project. Four team members had major management roles in this effort: Brian Price and Beth Borko of MITRE and Haven Whiteside and John W. Reuss of the Office of Strategic Assessment and Special Studies (OSASS).

Other members of the interdisciplinary team include the following:

Office of Strategic Assessment and Special Studies

John Agosta
Robert Barles
David Bennett
Valdis Goncarovs

The MITRE Corporation

Thomas Wolfinger

CONSAD Research Corporation

Alan Bernstein

International Research & Technology Corporation

Richard Meyer

Urban Systems Research & Engineering, Inc.

Peter Hall
Kevin Hollenbeck

Other persons who contributed to the report are as follows:

U.S. Environmental Protection Agency

Michael Bergman, Special Projects Office, RTP
Alvin Edwards, Strategic Assessment and Special Studies, ORD
Gloria Reese, Strategic Assessment and Special Studies, ORD
Mark Schaefer, Technical Information, ORD

The MITRE Corporation, Metrek Division

Judith Cambon
Edward Friedman
Dabney Hart
Sharon Hill
Richard Kalagher
Carol Kuhlman
Andrew Lawrence
Marc Narkus-Kramer
Sheila Pack
Daniel Schultz
John Wik
Joe Wisniewski

International Research & Technology Corporation

Donald Cooper
Ralph Doggett
Susan Hall
Mark Sayers
Robert Strieter
Ginger Spence

CONSAD Research Corporation

Nazir Dossani
Thomas Piwowar
Mary Reiter
Gabe Sucher

Urban Systems Research & Engineering, Inc.

Jean Banks
Robert Burke
Martha Connolly
Christian Demeter
Annuardha Deolalikar
Lee Dillard
Claire Nivola
Mark Stellwagen

Control Data Corporation

Carol Metzger
Shahen Tahmassian

Consultants

Yakov Haimes, Case-Western Reserve University
Frank Maslan, Private Consultant

Editorial Experts, Inc.

Hardy Dietz
Lola Zook

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INTRODUCTION

The Environmental Outlook reports published by the Office of Research and Development (ORD) are intended to provide information on environmental trends and future environmental problems to participants in the U.S. Environmental Protection Agency's long-range research and development (R&D) planning process. In particular, these reports are intended to provide such information in support of the Agency's annual Congressionally-mandated Research Outlook report, the R&D strategies developed by ORD's 13 Research Committees, and the Agency's budget planning process. These relationships are described further in Chapter 1.

Earlier editions of the Environmental Outlook were basically data handbooks that reported trends data on major air and water pollutants. Environmental Outlook 1980 is a much more ambitious report. The first two chapters describe the environmental and institutional context and the approach employed in producing the report. Chapter 3 describes societal trends, primarily trends in public attitudes about environmental protection and environmental policy. Chapters 4 (Air Pollutants) and 5 (Global Atmospheric Pollution) discuss trends in air pollutants and air quality problems. Chapters 6, 7, 8, and 9 focus on water: 6 on water pollution trends, 7 on drinking water, 8 on water resources, and 9 on marine pollution. Chapter 10 presents a discussion of trends and problems in solid and hazardous wastes. Discussions of toxic substances, radiation (ionizing and nonionizing), and noise follow in Chapters 11, 12, and 13. In light of the important relationship between energy and environment, Chapter 14 singles out energy for special attention.

A separate Summary Report is available.

CHAPTER 1
ENVIRONMENTAL AND INSTITUTIONAL CONTEXT

1.1 A PERSPECTIVE ON OUR ENVIRONMENTAL FUTURE

In the 10 or so years since environmental quality became a matter of great public concern, some progress has been made, particularly in controlling the most visible and obvious forms of environmental pollution. However, we have not achieved many of our stated environmental goals; in fact, the problems being addressed by the U.S. Environmental Protection Agency (EPA) and others are becoming more evident, more pervasive, and more difficult to control.

Hazardous wastes are a case in point. Several dramatic indications of the potential scope and intractability of this environmental problem have surfaced--first at Love Canal in New York, then at the "Valley of the Drums" in Kentucky, and more recently in old landfills in Arkansas.[1] Many other examples can be cited, and they tend to have one thing in common: specialists may (or may not) have known about them, but they caught society by surprise.

We do know, at least in a general way, what causes the problems with which EPA and others are currently wrestling. While some have "natural" origins, the root cause of a majority of environmental problems can be traced to human beings and their activities. Worldwide, both population and economic activity have been increasing for centuries. The U.S. population growth rate is much lower than the world average; nevertheless, our population is still increasing, and this growth is being distributed very unevenly. Ours is a highly industrialized, technological society. Although the economic growth rate is currently much lower than most Americans would like, the scale, intensity, and sophistication of industrial production in the United States are unprecedented.

Like citizens in other Western societies, we have generally accepted the proposition that economic growth is directly correlated with human welfare. We have also assumed that economic growth is

---

[1] It is estimated that a half million tons of hazardous wastes are improperly stored in the Erie and Niagara Falls area. Nearly 40,000 barrels of pesticide wastes were improperly disposed of in western Kentucky and are now in various stages of deterioration. Large landfills used for years as disposal sites for pesticide wastes have created serious land and water pollution problems over a wide area near Jacksonville, Arkansas.

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directly related to energy consumption. President Carter called our attention to this aspect of our national character in his speech to the nation on Sunday, July 15, 1979. The President also alluded to the interrelationships among energy, the economy, and the environment. The fact of these interrelationships has long been recognized, but the reality of having to wait in lines at gas stations, pay rising bills in times of double-digit inflation, and witness the horrifying effects of the inadequate disposal of hazardous wastes has reminded us in recent months of how much our daily lives are affected by energy, economic, and environmental policies.

By its very nature, this interdependence produces considerable tension in our political system. Currently, advocates of accelerated domestic energy production argue that our environmental protection goals should be given a lower priority than our energy goals. Numerous proposals have been made to relax environmental standards, delay compliance schedules, and grant environmental exemptions. These proposals generally have not been adopted--at least in part because the American public and its leaders continue to be strongly committed to protecting and improving environmental quality. However, there now appears to be an increasing realization that energy, economic, and environmental policies must be considered jointly in the development and implementation of regulations. Establishment of the Federal Regulatory Council, with EPA Administrator Douglas Costle as chairman, is one tangible outgrowth of this realization.

Much of the current frustration in the environmental area can be attributed to two sources: (1) unanticipated and unpleasant environmental surprises, such as Love Canal; and (2) lack of certainty about how to deal with some of the severe environmental problems, such as toxic substances, which we are, or may be, facing. Major efforts are under way in EPA and in other Federal departments and agencies to reduce this uncertainty and eliminate environmental surprises. One of the actions taken in EPA's Office of Research and Development (ORD) has been to establish a new unit--initially called the Strategic Analysis Group, and now the Office of Strategic Assessment and Special Studies.

1.2 STRATEGIC ANALYSIS AND EPA's LONG-RANGE R&D PLANNING PROCESS

The Office of Strategic Assessment and Special Studies (OSASS) is responsible for providing information on environmental trends and future environmental problems to participants in EPA's long-range research and development planning process depicted in Figure 1-1.

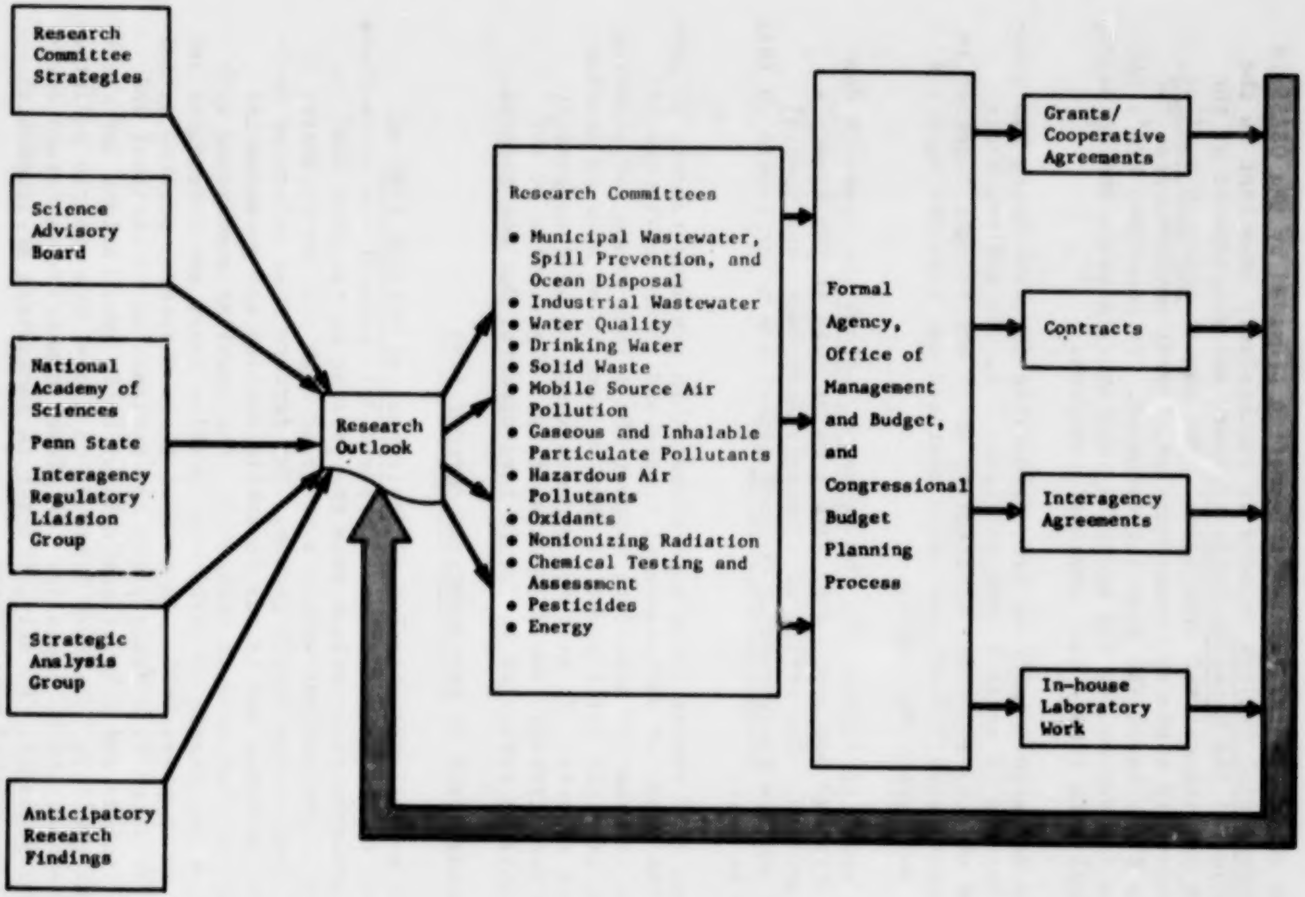
Research Committee Strategies
Science Advisory Board
National Academy of Sciences
Penn State
Interagency Regulatory Liaision Group
Strategic Analysis Group
Anticipatory Research Findings
Research Outlook
Research Committees
• Municipal Wastewater, Spill Prevention, and Ocean Disposal
• Industrial Wastewater
• Water Quality
• Drinking Water
• Solid Waste
• Mobile Source Air Pollution
• Gaseous and Inhalable Particulate Pollutants
• Hazardous Air Pollutants
• Oxidants
• Nonionizing Radiation
• Chemical Testing and Assessment
• Pesticides
• Energy
Formal Agency, Office of Management and Budget, and Congressional Budget Planning Process
Grants/ Cooperative Agreements
Contracts
Interagency Agreements
In-house Laboratory Work

FIGURE 1-1
EPA LONG-RANGE RESEARCH PLANNING PROCESS

The environmental futures information provided by the OSASS in its Environmental Outlook reports is particularly important in the preparation of the Research Outlook report and development of the Research Committees' R&D strategies. The annual Research Outlook, a Congressionally mandated, comprehensive, 5-year environmental R&D plan, is EPA's basic R&D planning document. It describes EPA's R&D programs for supporting the Agency's regulatory mission and preparing it to deal with future environmental problems.

The Research Committees are responsible for developing R&D strategies for the 13 areas listed in Figure 1-1. To achieve their intended objectives, these strategies, which are brought together in the comprehensive 5-year plan, also must address both the Agency's present and future R&D needs.

As shown in Figure 1-2, the Research Outlook and Research Committee strategy documents also have a major role in the Agency's budget process. The Office of Strategic Assessment and Special Studies and the Environmental Outlook report are major inputs to this process as well.

This 1980 report comes much closer than previous reports to providing the kinds of environmental trends and future environmental problems information needed to support EPA's long-range R&D planning. However, it still falls short of what we hope to be able to provide in future reports. To meet our expectations, we have to greatly improve our strategic analysis capability. The results of this effort will be reflected in future Environmental Outlook reports.

1.3 ORGANIZATION OF ENVIRONMENTAL OUTLOOK 1980

The overall organization of Environmental Outlook 1980 was described in the Introduction. Chapters 3-13 present our projections of the environmental outlook from the present to the year 2000, in the form of projections within a range of high and low estimates of economic and energy supply growth. The factors that determine environmental problems and trends in public opinion and governmental policies are discussed in Chapter 3. The problems associated with particular pollutants or particular problem areas are introduced and defined in Chapters 4-13. In most of these chapters, problem definition is followed by a description and explanation of national and regional trends and a brief analysis of their implications for environmental quality. Chapters 5 and 9, on global atmospheric pollution and marine pollution, emphasize the global dimension in future environmental problems. Finally, Chapter 14 summarizes environmental problems associated with energy.

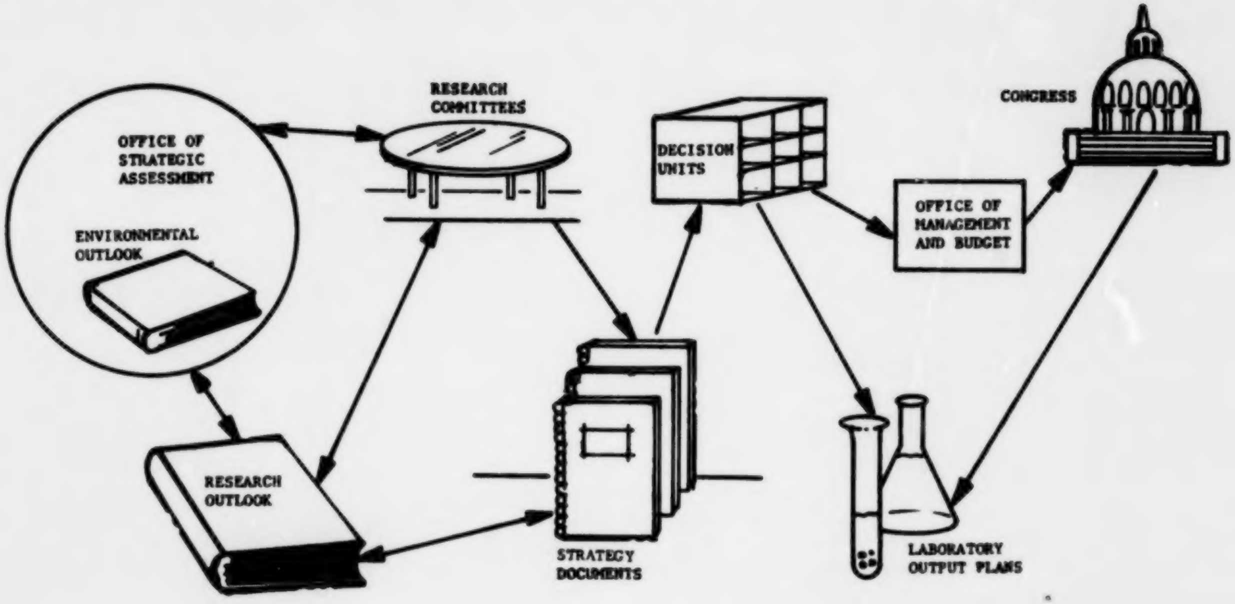
OFFICE OF STRATEGIC ASSESSMENT
ENVIRONMENTAL OUTLOOK
RESEARCH COMMITTEES
DECISION UNITS
CONGRESS
OFFICE OF MANAGEMENT AND BUDGET
RESEARCH OUTLOOK
STRATEGY DOCUMENTS
LABORATORY OUTPUT PLANS

FIGURE 1-2
R&D PLANNING AND THE BUDGET PROCESS

CHAPTER 2
APPROACH

2.1 INTRODUCTION

As stated in Chapter 1, the purpose of this Environmental Outlook report is to provide useful information on future environmental trends and problems for research and development planning. The overall approach, described briefly in this chapter, is a product of our attempt to meet the needs of the persons responsible for preparing the Agency's annual Research Outlook report and the members of the 13 Research Committees who prepare ORD's research strategy documents, to the greatest possible extent within the limitations of our current strategic analysis capabilities.

The interdisciplinary team preparing this report has used a variety of formal and informal models and analytical methods to produce both quantitative and qualitative results. Several different versions of chapters drafted by that team have been submitted for review to persons who worked on the Research Outlook 1980 report, develop the Research Committee strategies, and have regulatory program responsibilities. This review process is intended to produce a high quality, credible report which meets the needs of the persons it is intended to serve.

At present, the principal forecasting tool available to the Office of Strategic Assessment and Special Studies is the Strategic Environmental Assessment System (SEAS). This system, which was used extensively in Chapters 4 (Air Pollutants), 6 (Water Pollutants), 10 (Solid and Hazardous Wastes), and 14 (Energy and the Environment), is limited to projecting the quantities of selected pollutants and wastes which would be produced by various industries given a set of macroeconomic, demographic, energy, and environmental assumptions. Projections and analyses from other sources were used to (1) extend, supplement, and evaluate the SEAS projections when they were used, and (2) provide future environmental trends and problems information for pollutants and problems not covered by SEAS.

Our intent has been to go beyond a SEAS analysis to a "strategic environmental assessment" approach. However, since SEAS is the only formal model used in more than one chapter, it receives more attention here. The approach, data, and methods used in non-SEAS analyses vary among pollutants and problems, and they are described where appropriate in Chapters 3-14. In the remainder of this chapter, SEAS, the two SEAS scenarios, and how both SEAS and non-SEAS projections were analyzed are described. More details are provided in each chapter and in Appendices A and B. An attempt has been made to provide

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sufficient information about assumptions, data quality, data gaps, and results to permit the reader to make an independent evaluation of our results.

A final introductory point warrants special emphasis. The environmental trends presented in this report are, at best, rough approximations. Like all forecasts, our trend projections are a product of a variety of factors, including assumptions, data quality, and the models and methods used. Every effort has been made to be reasonable, thorough, systematic, and comprehensive, but, as stated earlier, Environmental Outlook 1980 is the first major step toward achieving the objectives set for the annual Environmental Outlook report, and much remains to be done.

2.2 THE SEAS MODEL

SEAS, originally developed by EPA and now maintained jointly by EPA and the Department of Energy, is an interactive computer model which functions via a set of energy, economic, regional, and environmental modules. The system is shown graphically in a simplified flow diagram, illustrated in Figure 2-1.

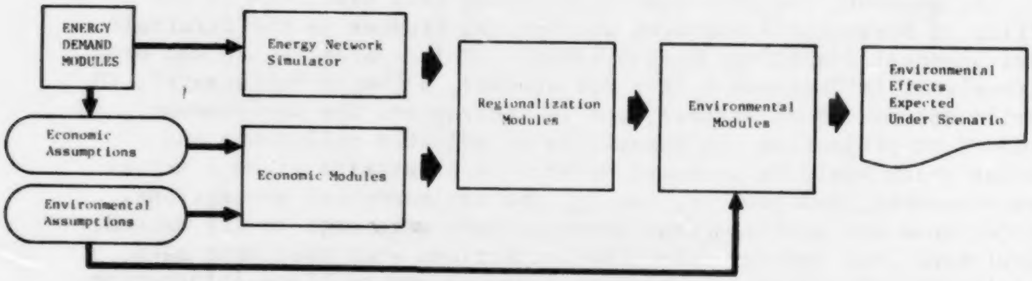
ENERGY DEMAND MODULES
Energy Network Simulator
Economic Assumptions
Environmental Assumptions
Economic Modules
Regionalization Modules
Environmental Modules
Environmental Effects Expected Under Scenario

FIGURE 2-1
A FLOW DIAGRAM OF THE SEAS COMPUTER MODEL

The energy and economic modules simulate energy consumption and economic activity to the year 2000; the regionalization modules separate these energy/economic data into various regional divisions and activity levels; the environmental modules then project the environmental pollution and resource requirements associated with these levels of activity.

Included among the environmental factors which SEAS can project are criteria air pollutants, trace elements released to air, conventional water pollutants, solid waste, and land and water use. The system can also project certain data regarding labor requirements and occupational health and safety hazards. These projections can be reported at the national level and for the 10 Federal Regions in EPA's regional organization (Figure 2-2).[1] They can also be reported for Air Quality Control Regions (AQCR), Standard Metropolitan Statistical Areas (SMSA), and other geographic regions.

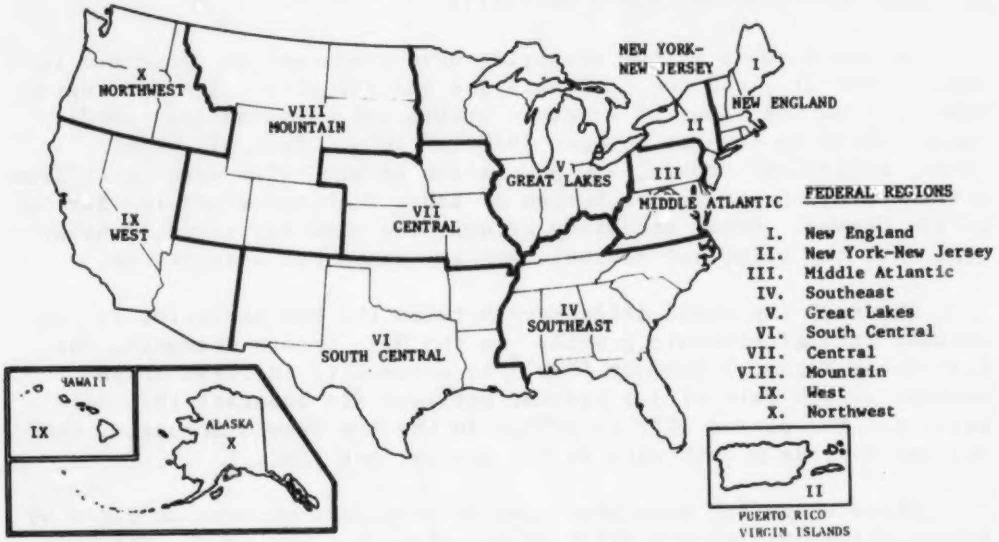
X NORTHWEST
VIII MOUNTAIN
IX WEST
VII CENTRAL
VI SOUTH CENTRAL
V GREAT LAKES
IV SOUTHEAST
III MIDDLE ATLANTIC
NEW YORK-NEW JERSEY
II
I
NEW ENGLAND
HAWAII
IX
ALASKA
X
II
PUERTO RICO
VIRGIN ISLANDS
FEDERAL REGIONS
I. New England
II. New York-New Jersey
III. Middle Atlantic
IV. Southeast
V. Great Lakes
VI. South Central
VII. Central
VIII. Mountain
IX. West
X. Northwest

FIGURE 2-2
MAP OF THE FEDERAL REGIONS

SEAS results take the form of economic projections (e.g., the aggregate value of goods and services produced in each sector of the economy, the unemployment rate, or the components of Gross National Product) and environmental projections (e.g., the quantities of pollution produced, expressed by pollutant type, industry, or groups of industries, or as a percentage of total national pollution).

---

[1] The EPA regions illustrated in Figure 2-2 are referred to as "Federal Regions" throughout this report.

The SEAS model generates two projections for most pollutants: "gross" and "net." Gross projections estimate the amount of pollutant generated by industrial and other activities without regard to any pollution control measures; in a sense, gross projections represent a "worst case." Net projections, on the other hand, estimate the amount of each pollutant that would be discharged to the environment if all wastes were cleaned enough to meet assumed pollution control regulations; thus, net projections represent a "best case." Given the validity of other assumptions, pollutant discharges by most sources would likely be somewhere between the SEAS gross and net estimates.

2.3 THE HIGH AND LOW GROWTH SCENARIOS

As noted earlier, two scenarios have been used to structure this report generally and the SEAS analyses specifically. The two represent alternative views of economic growth and environmental conditions likely to develop between 1975 and 2000. Economic growth rates, employment trends, and population growth rates were taken from estimates developed by the Bureau of Labor Statistics and the Bureau of the Census. Other necessary assumptions were specified, consistent with the principal economic and environmental assumptions.

The most important difference between the two scenarios is the assumed rate of economic growth. In the High Growth Scenario, the U.S. Gross National Product (GNP)[2] is assumed to increase at an average growth rate of 3.5 percent per year (in constant 1971 dollars) for the period 1975 to 2000. In the Low Growth Scenario, the assumed average growth rate is 2.6 percent per year.

These scenarios were developed to provide a reasonable range of future conditions within which to structure our analysis. The High Growth Scenario probably overestimates future economic growth, and the Low Growth rate is probably less than the U.S. economy will actually achieve.

The following paragraphs briefly explain only those assumptions most important to understanding how future environmental conditions would differ from the present under the two scenarios. Further detail on these assumptions is provided in Appendix B. The assumptions are discussed in the following order:

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[2] Gross National Product is defined as the money value of all final goods and services produced in a year. The main components of GNP are personal and private domestic investments, government purchasing and exports.

- Economic growth
- Population growth
- Energy supply and demand
- Environmental regulation

Some of the most important of these assumptions are listed in Table 2-1. The environmental implications of future reliance on different energy sources (e.g., coal, oil, nuclear) can be significant, so the supply and demand assumptions for various forms of energy are given particular attention.

2.3.1 Economic Growth

The GNP growth rates used in each scenario are illustrated in Figure 2-3. The GNP difference between the two scenarios in 2000 would be $565 billion at the assumed economic growth rates. Most of this difference comes from expected changes in personal consumption, with some additional difference resulting from growth in government purchases, which, in turn, are influenced by population growth.

The High Growth rate of 3.5 percent per year was derived from an unpublished estimate by the Office of Economic Growth, Bureau of Labor Statistics.[3] By comparison, actual GNP growth in the United States averaged 3.2 percent per year between 1946 and 1975,[4] and other projections of future economic growth range around 3 percent per year.[5] The Low Growth rate of 2.6 percent per year was chosen to represent a slower rate of economic growth.

2.3.2 Population Growth

Because high economic growth is assumed to be related to high population growth, population is projected to increase more rapidly in the High than in the Low Growth Scenario (an average 0.8 percent per year, compared to 0.6 percent). These growth rates were selected from a series of projections made by the U.S. Bureau of the

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[3] Based on a special run of the BLS input-output model for the U.S. Environmental Protection Agency, Office of Research and Development, April 1978. The same source provided other key demographic estimates, such as household size, labor force size, and unemployment rates.

[4] U.S. Department of Commerce, Bureau of Economic Analysis, Survey of Current Business, January 1976, November 1978, and April 1978.

[5] Based on an informal survey of major economic research organizations, recorded in SEAS Memo 170, dated January 9, 1979.

TABLE 2-1
PRINCIPAL SCENARIO ASSUMPTIONS

	High Growth	Low Growth
GNP Growth, 1975-2000[a] (percent per year)	3.5	2.6
Population Growth Rate[a] (percent per year)	0.8	0.6
Total Energy Supply, 2000 (quadrillion Btu)	124	105
Energy Supply Growth Rate[a] (percent per year)	2.1	1.5
Coal Supply, 2000 (percent of all energy supply)	35	31
World Oil Price[b] ($1971/barrel)	39.53	59.30
Growth in Oil Imports[a] (percent per year)	0.2	-1.2
Growth in Gas Imports[a] (percent per year)	1.1	4.2

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[a] All growth rates are expressed as the average for 1975 to 2000.
[b] This price is first reached in 1985.

NOTE: See Appendix B (Table B-10) for SEAS environmental regulation assumptions.

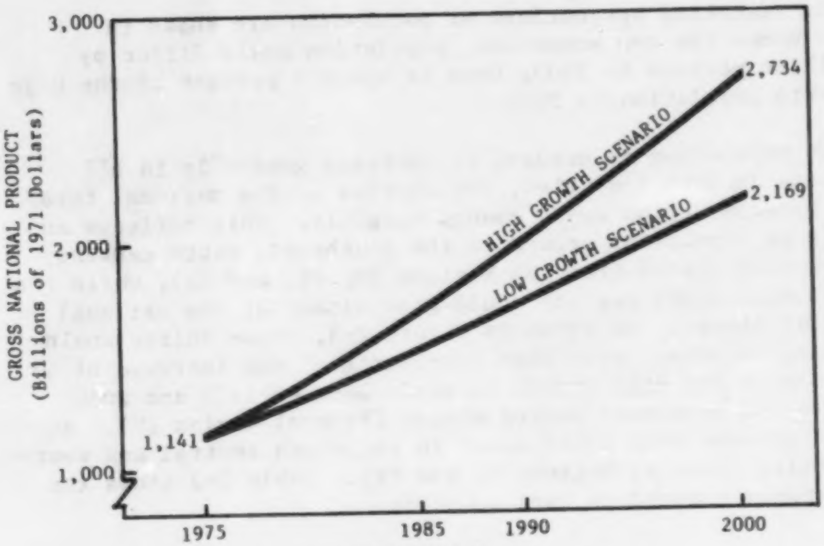

FIGURE 2-3
ASSUMED GROSS NATIONAL PRODUCT INCREASE IN HIGH AND LOW GROWTH SCENARIOS

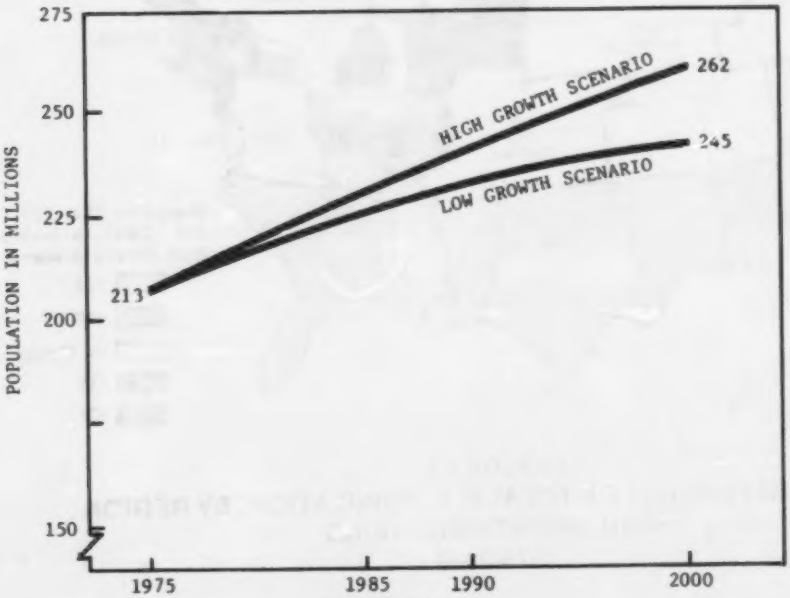

FIGURE 2-4
ASSUMED TRENDS IN U.S. POPULATION 1975-2000

Census.[6] The resulting projections of population are shown in Figure 2-4. Under the two scenarios, population would differ by about 15 million persons in 2000; this is about 6 percent of the High Growth Scenario population in 2000.

Although population is assumed to increase gradually in all Federal Regions in both scenarios, the portion of the national total represented by each region would change slightly. This reflects an assumed shift in population growth to the southeast, south central, and western United States (Federal Regions IV, VI, and IX), while the population in most other regions would grow either at the national average rate or slower. As shown in Figure 2-5, these shifts would not be extreme. However, more than one-fourth of the increase of 47 million persons in the High Growth Scenario between 1975 and 2000 would occur in the southeast United States (Federal Region IV). An additional 15 percent each would occur in the south central and western United States (Federal Regions VI and IX). Table 2-2 shows the regional increases assumed in each scenario.

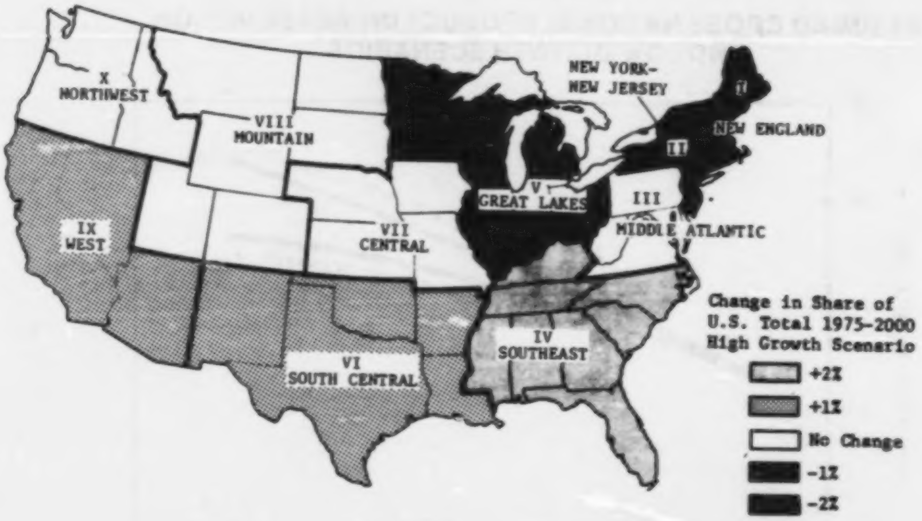
X NORTHWEST
VIII MOUNTAIN
NEW YORK-NEW JERSEY
I
NEW ENGLAND
II
V GREAT LAKES
III MIDDLE ATLANTIC
IX WEST
VII CENTRAL
IV SOUTHEAST
VI SOUTH CENTRAL
Change in Share of U.S. Total 1975-2000 High Growth Scenario
+2%
+1%
No Change
-1%
-2%

FIGURE 2-5
CHANGE IN PERCENT OF TOTAL U.S. POPULATION, BY REGION
HIGH GROWTH SCENARIO
1975-2000

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[6] U.S. Department of Commerce, Bureau of the Census, Current Population Reports, Series P-25, No. 310, 1977.

TABLE 2-2
REGIONAL POPULATION GROWTH
1975-2000

Federal Region[a]	1975		2000					
			High Growth			Low Growth		
	Population (millions)	Percent of Total	Increase (millions)	Percent of Total	Percent of Total Increase 1975-2000	Increase (millions)	Percent of Total	Percent of Total Increase 1975-2000
IV. Southeast	35	16	13	18	28	9	18	27
IX. West	23	12	8	13	16	5	12	17
VI. South Central	22	10	8	11	16	5	11	14
V. Great Lakes	45	21	5	19	11	4	20	13
III. Middle Atlantic	24	11	4	11	8	3	11	8
X. Northwest	7	3	2	3	5	1	3	5
I. New England	12	6	2	5	5	2	6	5
II. New York-New Jersey	25	12	2	10	4	1	11	5
VIII. Mountain	6	3	2	3	4	1	3	4
VII. Central	11	5	1	5	2	1	5	2
Total[b]	213	100	47	100	100	32	100	100

[a] In descending order of projected growth.

[b] Rounding may create inconsistencies in addition.

2.3.3 Energy Supply and Demand

The future use of energy in all forms will greatly affect pollutant emissions. For this reason, a number of detailed energy supply and use assumptions were incorporated into the scenarios.[7]

Total energy supply would expand at 2.1 percent per year under High Growth conditions and 1.5 percent per year in the Low Growth Scenario. Most of this growth would be achieved by burning coal, increasing nuclear electricity generation, and recovering oil from western oil shales.

The projected use of energy by transportation, residential, commercial, industrial, and export activities is shown in Figure 2-6. Overall, the demand for energy by these activities would increase in the High Growth Scenario by 60 percent between 1975 and 2000, from about 50 quads to 85 quads per year. The comparable increase in the Low Growth Scenario would be about 33 percent, rising to a demand of 70 quads in 2000.

2.3.4 Environmental Regulation

The laws and regulations for controlling major sources of pollution in the United States are summarized in Chapter 3, and the major recent laws and regulations are discussed in Appendix B. They are the same for both scenarios and are explained in greater detail in the introductions to Chapters 4-13. Their effects on SEAS projections of pollutant discharges are discussed in chapters presenting such projections and in Appendix B.

2.4 ANALYSIS OF TRENDS

SEAS projections of the quantities of pollutants that would be present in untreated wastestreams are referred to as "gross" generation of pollutants. "Net" emission of pollutants, on the other hand, refer to the quantities that would be released to the environment based on the application of assumed control technologies that meet applicable standards. For those pollutants covered by SEAS, pollutant projections were estimated for each scenario for the years 1975, 1985, 1990, and 2000. To produce these projections, economic projections were made for each year from 1975 to 2000.

In analyzing SEAS results, pollution trends for the nation and for each of the Federal Regions were identified and compared. Industry by industry trends were also examined to attempt to identify the causes of any changes over the period from 1975 to 2000.

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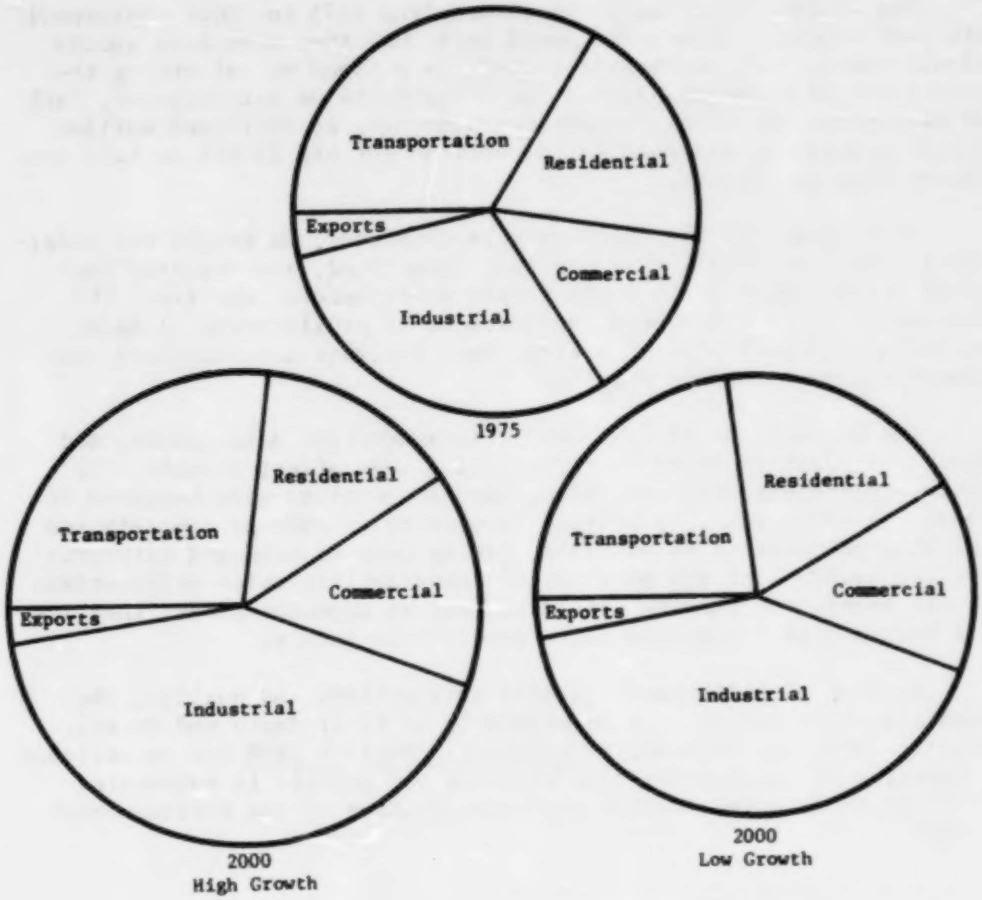
[7] These assumptions are described in greater detail in Appendix A and in Chapter 14.



	1975		2000 High Growth Scenario		2000 Low Growth Scenario	
	10^{15} Btu	Percent of Total	10^{15} Btu	Percent of Total	10^{15} Btu	Percent of Total
Transportation	18	34	23	27	16	23
Residential	10	19	12	14	13	18
Commercial	7	14	13	15	11	15
Industrial[a]	16	30	35	42	29	41
Exports	2	3	2	3	2	3
Total[b]	53	100	85	100	70	100

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[a] Includes demand for oil and natural gas as chemical feedstocks.

[b] Rounding may create inconsistencies in addition.

FIGURE 2-6
MAJOR ENERGY DEMAND ASSUMPTIONS

Our analyses highlight the change from 1975 to 2000. Intermediate year projections are discussed only when they have some special significance, such as showing a break in a trend or reflecting the imposition of a new standard. The emphasis is on net releases, rather than gross pollutant generation--although, as explained earlier, actual quantities released to the environment are likely to fall between these two values.

Once these initial analyses were completed, we sought the underlying causes of trends that had been identified, and analyzed what these trends might imply about future environmental quality. The discussion of environmental implications is preliminary. A major emphasis will be placed on making these analyses more complete and comprehensive in future reports.

The discussions of SEAS projections describe data quality and gaps, and identify model characteristics that affect results. If other projections were available, SEAS projections were compared to them. In every case, an attempt is made to provide as complete and reliable projections as possible, taking care to note and interpret the implications of any problems of comparability which might exist. In all cases, the results should be read as approximations; they are not intended to be an attempt to predict the future.

Because of differences in data availability and quality, the chapters which follow vary considerably in their depth and detail. Despite these limitations, Environmental Outlook 1980 has established a baseline of information from which we can proceed in succeeding editions to detailed, problem-oriented studies of the environmental future.

CHAPTER 3
SOCIETAL TRENDS

HIGHLIGHTS OF CHAPTER 3

- Public support for environmental protection measures has steadily increased since 1970. During the 1979 "gasoline crisis," the public indicated support for slowing down, but not abandoning, efforts to achieve environmental goals in order to decrease dependence on foreign energy sources. But basic support for environmental protection apparently remains strong.
- Legislative trends reveal that vigorous efforts are being made to implement and enforce environmental laws while simultaneously minimizing regulatory impacts on energy and the economy.
- Environmental problems have received considerable attention internationally. Progress includes establishment of new international organizations and a range of bilateral agreements as well as the addition of environmental programs in existing organizations, such as the North Atlantic Treaty Organization and the Organization for Economic Cooperation and Development.
- In economically developed countries other than the United States, environmental programs are being institutionalized and steady progress is being made to control point source air and water pollutants. In contrast, many developing countries have thus far not addressed the dilemma between the need to meet basic human needs and to protect a seriously deteriorating environment.

3.1 INTRODUCTION

Among the various factors that will shape our environmental future, most relate to human activities. Several major "determinants" of environmental quality and change are discussed briefly in this chapter, and trends in public perceptions and governmental policies concerning environmental quality are outlined. The trends presented here, unlike those described in the remaining chapters, are oriented to the past rather than the future.

3.2 GENERAL DETERMINANTS OF ENVIRONMENTAL QUALITY AND CHANGE

The environment is constantly changing. Those changes not resulting from human efforts to control the environment are usually continuous, evolutionary, slow, and largely predictable. In contrast, human attempts to farm, domesticate, produce, manufacture, conquer, defend, and even to protect the environment, seem to have more potential for producing discontinuous, significant changes, either deliberately or by accident.

Natural changes of sudden global significance are rare. In the absence of intervention, the genetic diversity and distribution of established species assure gradual change and continuous production of "renewable natural resources." Intervention by humans or nature can change this; for example, the income of solar energy evidences some cyclical variation that affects climate, but over the next two decades, striking climatic changes due to natural processes are not expected.

Individual floods, hurricanes, and volcanic eruptions cause environmental changes, most of which are localized and short-lived. Exceptions inevitably arise; for example, there is evidence that ash from the volcanic eruption on Krakatoa in 1883 had global climatic significance.[1] However, ash-producing eruptions or other natural events of this magnitude are rare.

Most of the trends discussed in this Outlook account for the effects of human activities by extrapolating from the present. In particular, the SEAS computer model described in Chapter 2 explicitly includes projected technological change from both existing and anticipated technologies and compliance with current environmental regulations. These projections do not anticipate what, if any, changes might take place in public values and attitudes toward the environment, nor do they forecast future changes in governmental policies. However, both kinds of changes might well alter the environmental outlook. Consequently, the discussion in this chapter includes trends in both public perceptions and governmental policies.

3.3 PUBLIC PERCEPTIONS

3.3.1 Development of Concern for the Environment

A number of direct and indirect indicators can give a general sense of public perceptions, opinions, and attitudes concerning the environment and environmental quality. These indicators may include the formation and activities of environmental interest groups, results of public opinion polls, responses to books which promote environmental values or sound an environmental alarm, and enactment of legislation and regulations to protect and improve environmental quality. None of these, either separately or in combination, is an altogether satisfactory indicator; however, they all show, to some degree, how the public and its leaders feel about the environment.

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[1] "Inadvertent Climate Modification," in Report of the Study of Man's Impact on Climate, MIT Press, Cambridge, 1971, pp. 279-283.

The list of significant environmental events presented in Table 3-1 illustrates several changes in our attitudes toward the environment. From the 1870s into the 1930s, the major emphasis was on conserving natural resources. Over the past four decades, the focus has been more on achieving public health benefits of clean water and clean air. Most recently, the government has responded to a growing awareness that human activities can produce irreversible environmental damage, and has taken steps to combat the causes of such damage.

Opposition to the misuse of natural resources was at the heart of the conservation movement, which was spearheaded by a number of privately funded conservation organizations. Their common objective was the appropriate use of natural resources. However, they shared neither common concepts nor definitions of appropriate use. For some, conservation meant environmental management (e.g., scientific forestry, or damming and channeling of rivers), and for others, conservation was equated with preservation.

The conservation debate continues today, and it still focuses on such things as dams and wilderness areas. For example, Congress was sharply divided in reaching its decision to exempt the Tellico Dam project on the Little Tennessee River from the provisions of the Endangered Species Act; open public conflict has been evident as the U.S. Forest Service has moved to implement President Carter's directive to prepare wilderness proposals for areas east of the Rockies;[2] and public participation in the Roadless Area Review and Evaluation process has often generated acrimonious debate.[3]

Another early theme still very much in evidence is public health. The recognition that urban environments were associated with air and water pollution and rapid spread of infectious disease generated strong public support for the public health initiatives of the late nineteenth century. The construction of the Panama Canal in the early 1900s taught Americans the importance of sanitation in controlling diseases--in this instance, yellow fever. The Panama Canal episode illustrates an early Federal public health effort; however, most government public health action at that time was at the state level and focused on preventing disease by such measures as providing safe drinking water.

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[2] Carter, J., Message to the Congress of the United States, The White House, May 23, 1977.

[3] "Sharp Division Remains on Establishment of Wilderness Areas," Addison Independent, Middlebury, Vermont, July 19, 1979.

TABLE 3-1
A SELECTIVE LIST OF U.S. ENVIRONMENTAL EVENTS, 1872-1979

Date	Event
1872	First National Park (Yellowstone) established
1875	American Forestry Association founded
1892	Sierra Club founded
1897	National Forests established (Act of June 4, 1897)
1908	President Roosevelt held White House Governors' Conference on Conservation
1912	Public Health Service Act passed (PL 62-265)
1933	President Roosevelt's "New Deal" created Civilian Conservation Corps
1939	Soil Conservation Service built more than $300 million in sewage treatment projects
1947	Federal Insecticide, Fungicide, and Rodenticide Act (PL 80-104) passed
1948	First national water pollution control legislation passed: Water Pollution Control Act (PL 80-845)
	Donora, Pennsylvania, air pollution disaster
1955	First national air pollution control legislation passed: Air Pollution Control-Research and Technical Assistance Act (PL 84-159)
1962	Rachel Carson's Silent Spring published
1963	Clean Air Act (PL 88-206) passed
1964	Wilderness Act (PL 88-577) passed
1965	Motor Vehicle Air Pollution Control Act (Amendments to Clean Air Act) (PL 89-272) passed

(continued)

TABLE 3-1 CONTINUED

Date	Event
1966	Federal Court ruling in the *Storm King* case granted standing to environmental groups and recognized injuries to aesthetic and conservationist values
1969	Santa Barbara oil blowout
	Endangered Species Conservation Act (PL 91-135) passed
	National Environmental Policy Act of 1969 (PL 91-190) passed
1970	President Nixon presented first Presidential Message on the Environment to Congress
	In *Wilderness Society v. Hickel*, it was ruled that the Alaska pipeline required an environmental impact statement, and construction was suspended
	Earth Day initiated
	Environmental Protection Agency created (Reorganization Plan No. 3)
1972	UN Conference on the Environment held in Stockholm
	Marine Protection, Research, and Sanctuaries Act (PL 92-532) passed
1973	Arab oil embargo
1974	Energy Supply and Environmental Coordination Act (PL 93-319) passed
	Congress approved Alaska pipeline over environmentalist objections, suspending earlier court rulings
	Safe Drinking Water Act (PL 93-523) passed
1976	Toxic Substances Control Act (PL 94-469) passed
	Resource Conservation and Recovery Act (PL 94-580) passed

(continued)

TABLE 3-1 CONCLUDED

Date	Event
1977	Major amendments to Clean Air Act (PL 95-95) passed
	Water Pollution Control Act (Clean Water Act, PL 95-217) passed
1978	Major energy legislation (PL 95-617, -618, -619, -620, -621) passed
1979	President Carter ordered consideration of environmental effects abroad of major Federal actions (Executive Order No. 12114)

Source: Adapted from Mitchell, R.C. and J.C. Davies, III, "The United States Environmental Movement and Its Political Context: An Overview," Discussion Paper D-32, Resources for the Future, Washington, D.C., May 1978.

The Federal government initiated the steps that have given it a leading role in improving environmental quality in more general terms in 1948, with passage of the comprehensive Water Pollution Control Act (PL 80-845). In 1955, it followed with the Air Pollution Control, Research and Technical Assistance Act (PL 84-159). These Federal actions coincided with a growing public awareness of increasingly serious water and air pollution problems.

Sometimes a single individual plays an important role in calling attention to a problem needing public action, as Rachel Carson did in 1962 with publication of Silent Spring. This catalytic event ushered in a new era of environmental awareness. Carson's message was that overuse of chlorinated hydrocarbon pesticides (such as DDT) was leading to concentration of residues in birds' tissues, as these pesticides moved up the food chain. She pointed to dire reproductive effects and argued that DDT was poisoning the environment.

Rachel Carson, and those mobilized by her work, raised the public's environmental consciousness. Numerous organizations arose, including environmental law firms, and special celebrations such as Earth Day were held. In fact, the ensuing period might well be labeled "the decade of the environment."

What led to the changes of public perception epitomized by a "decade of the environment"? While specific causes are difficult to establish, it is possible to identify categories of causes. Problems can achieve public prominence and receive priority treatment by government as a consequence of singular events, such as the 1948 air pollution disaster in Donora, Pennsylvania, and the 1969 oil blowout in the Santa Barbara Channel. Pervasive environmental changes, such as the "death" of Lake Erie, smog in Los Angeles, or the red skies of Gary, Indiana, provide visible evidence that all is not well with the environment. Shortages of resources, such as gasoline in 1973 and 1979, and natural gas in the winter of 1976, attract everyone's attention.

It is clear that the public and its leaders often respond to a single occurrence, particularly if it is sufficiently dramatic and visibly affects people, animals, or plants. An occurrence with less immediate or apparent impact upon individuals may also bring about change, if its effects are persistent. It seems that ordinary citizens are "risk averse"[4] and will respond to clearly perceived risks.

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[4] Ashford, N., comments at Congress/Science Forum on Risk/Benefit Analysis: Its Role in Congressional Science and Technology Policy Decisions, Rayburn House Office Building, July 24, 1979.

3.3.2 Trends in Public Opinion

A more direct way of evaluating change in public attitudes and values is through public opinion polls. Only for the last 15 years have polls attempted to determine the public's environmental concerns. In a 1965 poll, when George Gallup asked which of 10 national problems should be given most attention, "reducing pollution of air and water" ranked ninth, but in an April 1970 poll this problem ranked second.[5] An obvious question is whether this change reflected temporarily heightened concern in response to Santa Barbara, Earth Day, or some other event, or whether it indicated a more fundamental shift in environmental values.

Analyses of data from polls taken after 1970 generally indicate a steady growth in strong public support for measures to improve environmental quality. By August 1975, Opinion Research Corporation was advising its business clients that even under the pressures of recession, high unemployment, and rising fuel costs, the public's support for the environment remained undaunted. In analyzing the results of this poll, ORC emphasized that "the opinions of people at all levels of society indicate that environmental protection has become a relentless, institutionalized, mass movement with the potential to change the future course of industrial history."[6]

In 1977, Opinion Research Corporation refined its analysis, noting that fewer respondents were finding pollution a serious problem where they lived.[7] However, the pollsters concluded that the public was unwilling to risk losing any gains and continued to support improving and protecting environmental quality. This finding is tempered somewhat by the responses to a question which asked whether greatly reducing air and water pollution is more important than expanding industrial production and jobs: 42 percent said the latter was more important; 29 percent said that reducing pollution was more important; and 18 percent said that both were important.[8] Even in this case, a majority (53 percent) said that, in areas where air quality is currently better than required under national standards, air quality should be maintained.[9] Opinion Research Corporation concluded that, in 1977, a majority of the public took a reasonable, balanced view while remaining committed to protecting the environment.

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[5] Mitchell, R., "Environment: An Enduring Concern," Resources, Vol. 57, January-March 1978, p. 1.

[6] Opinion Research Corporation, "Public Attitudes Toward Environmental Tradeoffs," Public Opinion Index, Vol. 33, August 1975. Based on a national probability sample of 1,222 persons age 18 and older, conducted between May 30 and June 22, 1975.

[7] Opinion Research Corporation, "Public Attitudes Toward Air and Water Pollution," Public Opinion Index, Vol. 35, February 1977. Based on a national probability sample of 1,003 persons age 18 and older, conducted between January 7 and January 14, 1977.

[8] Ibid, p. 16. The question asked was: "In order to really cut down pollution from the current levels, some companies may have to reduce their growth, meaning less production and fewer jobs. Do you think now it is more important to greatly reduce air and water pollution, or more important to expand industrial production and jobs?"

Perhaps a more important reference point for future environmental values is how environmental concerns have fared in the face of challenges such as Proposition 13, the energy crisis, and protracted "stagflation." Results from national surveys conducted through 1978 show that:

- More than half (52 percent) of those who feel taxes to be "very unreasonable" feel that continuing improvements made to protect the environment must be made "regardless of cost."[10]
- Almost half of those polled (45 percent, a plurality) feel that the "toughest environmental standards possible" should be enforced "even if they increased the cost of things to both business and the consumer."[11]
- By 47 percent to 31 percent, the public feels that "protecting the environment" is more important than "producing energy."[12]

In September and October 1978, Opinion Research Corporation conducted a national survey of 102 "Washington thoughtleaders" and compared their opinions with those of the "public."[13] The "thoughtleaders" interviewed included legislators, regulatory and other government officials, union leaders, public interest group leaders, and media representatives. The responses made by "thoughtleaders" and the "public" to statements about environmental protection and economic growth are compared in Figure 3-1. Clearly, in the fall of 1978, the "public," unlike the "thoughtleaders," did not believe that environmental protection and economic growth could be achieved at the same time. Also, by their responses, the public showed that it considered environmental protection so important that it might also accept slower economic growth in order to protect the environment.

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[9] Thirty-eight percent said standards should be relaxed.

[10] Mitchell, R. C., "The Public Speaks Again: A New Environmental Survey," Resources, Vol. 60, September-November 1978, p. 4.

[11] Harris, L., ABC News-Harris Survey, released January 4, 1979.

[12] Mitchell, R. C., "The Public Speaks Again: A New Environmental Survey," Resources, Vol. 60, September-November 1978, p. 3.

[13] Opinion Research Corporation, "Attitudes of Washington Thoughtleaders Toward the Future Availability and Use of the Nation's Basic Resources and Materials, Public Opinion Index, Vol. 37, Mid-February 1979. Public responses are from a national probability sample of 1,002 persons age 18 and older. Individuals interviewed in the "thoughtleader" study are not representative of any particular group but should be considered "purposive" samples of people prominent and highly influential in regard to governmental affairs.

The "gasoline crisis" in the summer of 1979 seems to have caused a shift in public opinion, especially when energy and environmental goals appear to be in conflict. A Harris poll conducted in July, at the height of the crisis, found that, by a 56-36 percent margin, respondents were willing to ease environmental restrictions to lessen dependence on foreign oil.[14] An even larger majority, 69-25 percent, was willing to pay more for synthetic fuels than for oil from foreign sources.[15] This survey was conducted before President Carter announced his energy plans. An Opinion Research Corporation poll taken in early August, after the President announced his synfuels program, found the public divided (41 percent yes, 42 percent no) on the question of whether a massive program to develop alternative sources of fuel would be likely to lead to serious environmental problems. Of the 42 percent who believed serious environmental risks were likely to be encountered, 58 percent believed that the risk was worth taking to reduce the nation's dependence on foreign oil.[16]

Both ABC News-Harris Survey and Opinion Research Corporation analysts recommend caution in interpreting these findings; the findings seem to represent a change in perceptions. That is, a majority of the public no longer believes that we can achieve all of our energy and environmental goals simultaneously. Becoming less dependent on insecure foreign energy sources has become more important during this most recent period of energy shortages. However, both ABC-Harris and Opinion Research analysts see this shift in public opinion as willingness to slow the pace of, but not to forego, achieving our environmental quality goals. Apparently, public concern for the environment remains firmly established.

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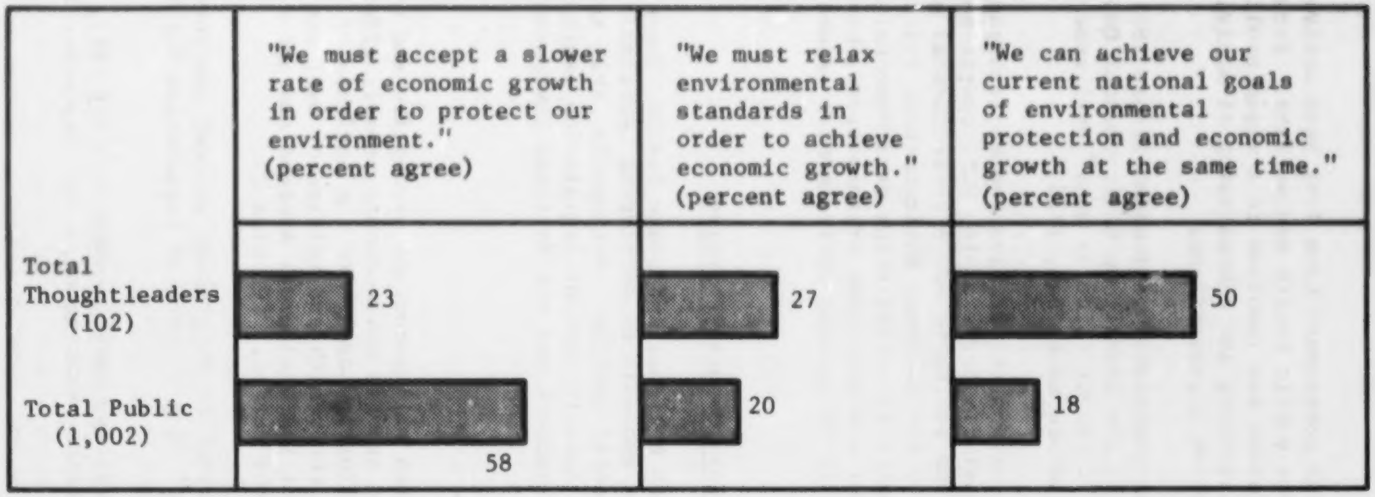
[14] Harris, L., ABC News-Harris Survey, released August 14, 1979. Based on a nation-wide telephone survey of 1,496 adults conducted between July 17 and 21, 1979.

[15] Ibid.

[16] Personal communication, Kenneth Schwartz, Vice President and Managing Director, Opinion Research Corporation Public Opinion Index. Based on telephone interviews of 1,010 persons of 18 years and older conducted between August 2 and 5, 1979.



"No opinion" omitted

[a] "Here are three statements about environmental protection and economic growth. Please tell me which statement you agree with the most."

Source: Adapted from Opinion Research Corporation, Public Opinion Index, Vol. 37, Mid-February 1979, p. 6. Used with permission.

FIGURE 3-1
ATTITUDES TOWARD ENVIRONMENTAL PROTECTION VERSUS ECONOMIC GROWTH[a]

3.3.3 Organized Groups

Organizations outside the government have long been active in efforts to protect and improve public health and welfare. Growing worldwide environmental awareness has resulted in a rapid proliferation of environmental organizations and a broadening of activities of long-established conservation organizations.

Major U.S. environmental organizations founded before 1971 are listed in Table 3-2. In 1973, the Council on Environmental Quality (CEQ) found that there were "...about twice as many" environmental organizations as there were before Earth Day, 1970.[17]

Recently, environmental organizations have become important participants in public policy making. For example, U.S. courts have affirmed the legal right of the public to argue environmental questions in court, as provided by the National Environmental Policy Act of 1969. This has given impetus to establishing environmental law firms, which, along with other environmental organizations, have become increasingly involved in litigating environmental issues.

3.4. U.S. LEGISLATION

3.4.1 Background Trends in Governmental Policies

Since about 1950, at both national and state levels, there has been a trend toward increased emphasis on developing legislation to protect and improve environmental quality. Nationally, this trend began with the air and water quality control legislation mentioned earlier. Another important landmark was the National Environmental Policy Act (NEPA) of 1969.

This Act established

> ...a national policy which will encourage productive and enjoyable harmony between man and his environment; promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man; and enrich the understanding of the ecological systems and natural resources important to the Nation. (Section 2)

Following NEPA, a succession of Congresses enacted environmental legislation, in some cases building on earlier legislation but also

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[17] Council on Environmental Quality, Environmental Quality 1973, U.S. Government Printing Office, Washington, D.C., September 1973, p. 396.

TABLE 3-2
AMERICAN ENVIRONMENTAL ORGANIZATIONS, BY DATE OF FOUNDING
(1870-1970)

Date	Event
1870	American Fisheries Society
1875	American Forestry Association
1876	Appalachian Mountain Club
1892	Sierra Club
1900	Society of American Foresters
1905	National Audubon Society
1911	North American Wildlife Foundation
1915	Ecological Society of America
1917	Commission for the Preservation of Natural Conditions (forerunner of the Nature Conservancy)
1919	National Parks and Conservation Association
1922	Isaak Walton League
1925	Defenders of Wildlife
1932	National Reclamation Association
1935	The Wilderness Society
1936	National Wildlife Federation The Wildlife Society
1941	Soil Conservation Society of America
1946	Wildlife Management Institute
1947	Conservation Education Association
1948	The Conservation Foundation American Conservation Association
1950	The Nature Conservancy
1954	Citizens Committee on Natural Resources
1965	Citizens for Clean Air
1967	Environmental Defense Fund
1968	Center for Study of Responsive Law
1969	Friends of the Earth
1970	Natural Resources Defense Council Sierra Club Legal Defense Fund Environmental Action Coalition Concern, Inc.

taking new initiatives. These laws give tangible evidence of an increased concern for the environment on the part of both the public and the Congress.

The following sections briefly examine the chronological development of the Federal-state relationship in environmental legislation, outline the objectives and approaches of major legislation, and look at recent regulatory actions as indicators of future trends.

3.4.2 The Federal-State Relationship

The power to protect the environment was not specifically delegated by the Constitution to the United States and, therefore, in some measure was reserved to the states under the Tenth Amendment. At the same time, Article One, Section Eight of the Constitution specifically delegates to the Congress the power to provide for the general welfare and to regulate interstate commerce. These three Constitutional principles serve as a starting point for a brief analysis of the Federal-state relationship in environmental affairs, particularly in the promulgation of laws to protect air quality.

Air quality legislation illustrates how the Federal role has evolved. Although air quality problems were evident in the 1948 Donora, Pennsylvania, disaster and in recurring episodes in Los Angeles, Pittsburgh, and other urban areas, it was seven years before enactment of the first Federal response--the Air Pollution Control-Research and Technical Assistance Act of 1955 (PL 84-159). Even then, the Congress did not claim legislative power in environmental regulatory matters. The Senate Committee on Public Works stated:

> The committee recognizes that it is the primary responsibility of State and local governments to prevent air pollution. The bill does not propose any exercise of police power by the Federal Government and no provision in it invades the sovereignty of States, counties, or cities. There is no attempt to impose standards of purity.[18]

The Congress did act, however, "...in recognition of the dangers to the public health and welfare,... to preserve and protect the primary responsibilities of the states and local governments in controlling air pollution"[19] and to aid technical research and state and local governmental air pollution control agencies. Protection of the public health and welfare was to become a recurrent theme in subsequent Federal legislation.

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[18] Senate Report 84-389, quoted in "1955 U.S. Code Congressional and Administrative News," 84th Congress--First Session, West Publishing Company, St. Paul, Minnesota, p. 2459.

[19] Ibid, p. 351.

In 1963, in response to President Kennedy's charge "...to take action to abate interstate air pollution,"[20] the Congress expanded the Federal role with passage of the Clean Air Act (PL 88-206). This Act directed Federal action on interstate air pollution through conferences, public hearings, and ultimately, legal suits by the Attorney General at the request of the Secretary of the Department of Health, Education, and Welfare. Two of the original Congressional findings stated in the Act have become recurrent themes:

> ...that the predominant part of the Nation's population is located in...metropolitan...areas, which generally cross the boundary lines of local jurisdictions and often extend into two or more States,...

and

> ...that the prevention and control of air pollution at its source is the primary responsibility of States and local governments.[21]

The Clean Air Act has retained these themes throughout all subsequent amendments. Therefore, Federal actions may respond directly to problems of an interstate nature, or to problems that the states face in meeting their responsibilities for air pollution control at the source.

In 1965, another theme was added--national standards to protect public health and welfare. In the Motor Vehicle Air Pollution Control Act of 1965, the dominant theme was health and welfare, and emission standards for new motor vehicles or engines were ordered. The interstate commerce clause provided an important basis for this Act.

In the Air Quality Act of 1967, the focus on assistance to the states was maintained, and consultation with the states was directed in establishing air quality control regions. However, to protect the public health and welfare, that Act required the Federal government to develop and issue air quality criteria and the states to adopt ambient air quality standards based on those criteria. The Act also required states to adopt regulatory measures to implement the ambient standards. Federal action was authorized in cases where state or local action was inadequate to address interstate pollution problems.

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[20] "1963 U.S. Code Congressional and Administrative News," 88th Congress--First Session, West Publishing Company, St. Paul, Minnesota, p. 1262.

[21] Ibid, p. 433.

Finally, the 1970 amendments established a comprehensive Federal-state partnership to address air pollution problems. This included, for the first time, Federal establishment of national ambient air quality standards. In short, by 1970, the Federal responsibility to act in environmental matters to protect the public health and welfare was definitely established.

3.4.3 Major Environmental Legislation--Objectives and Approaches

In addition to its general goal of protecting the environment, each piece of environmental legislation has specific objectives and approaches for meeting those objectives. Table 3-3 gives the objectives of some of the major legislation and the stated means for achieving them.

Air Quality Legislation

The first Federal legislation concerned exclusively with air pollution (in 1955) authorized $5 million annually to the Public Health Service of the Department of Health, Education, and Welfare (HEW) for research, data collection, and technical assistance to state and local governments. The Clean Air Act of 1963 (PL 88-206) provided grants to air pollution agencies for control programs and provided Federal enforcement authority for interstate air pollution problems. The 1965 Amendments to the Clean Air Act (PL 89-272) ordered national regulation of air pollution for new motor vehicles. The Air Quality Act of 1967 established a regional approach, requiring that the Secretary of HEW designate air quality control regions and promulgate air quality criteria describing the harmful effects of air pollutants.

With the passage of the Clean Air Act Amendments of 1970 (PL 91-604), air quality management attained a national, no longer regional, focus. The Act required the Administrator of the newly created Environmental Protection Agency to establish national ambient air quality standards (NAAQS) as well as national emission standards for significant new pollution sources and for all facilities emitting hazardous substances. However, states were left free to establish stricter standards. The Act also called for State Implementation Plans (SIPs) under which the states, subject to approval by EPA's Administrator, set emission standards for existing sources to achieve primary and secondary national air quality standards. Primary

TABLE 3-3
OBJECTIVES AND APPROACHES FOR CARRYING OUT OBJECTIVES OF MAJOR ENVIRONMENTAL LEGISLATION

Environmental Component Affected	Most Recent Legislation	Objectives of Legislation	Types of Pollutants Considered	Approach and Requirements for Carrying Out Objectives^a
Air Quality	Clean Air Act Amendments of 1977 PL 95-95	o Protect and enhance quality of air resources to promote public health and welfare o Establish national research and development program for prevention and control of air pollution o Provide assistance to states for air pollution control programs	o Criteria pollutants sulfur dioxide particulates carbon monoxide photochemical oxidants hydrocarbons nitrogen oxides lead o Hazardous air pollutants asbestos beryllium mercury vinyl chloride	o National Ambient Air Quality Standards (NAAQS) [109] o State Implementation Plans (SIPs) [110] o National Emission Standards for Hazardous Air Pollutants (NESHAPs) [112] o New Source Performance Standards (NSPS) [111] o Emission standards for new motor vehicles or motor vehicle engines [202]
Water Quality	Clean Water Act of 1977 PL 95-217	Restore and maintain the chemical, physical, and biological integrity of the nation's waters by: o Eliminating pollutant discharge into navigable waters by 1985 o Achieving water quality suitable for protection and propagation of aquatic life and water recreation o Prohibiting the discharge of toxic pollutants in toxic amounts	Specified pollutants discharged into water [502(6)] including: o Conventional pollutants (BOD, suspended solids, fecal coliform, and pH) [304(a)(4)] o Toxic pollutants (65)^b [304(a)(c)] o Nonconventional pollutants (neither of the above) [301(2)(F)]	o New Source Performance Standards (NSPS) [306(b)(1)] o National Pollutant Discharge Elimination System [NPDES] [301(b)(2)] o Combination of technology standards (e.g., "best practicable control technology," [301(a)(1)(A)], effluent limitations (308), state water quality standards (303), and toxic effluent standards [3[illegible]7(a)]

(Continued)

TABLE 3-3 CONCLUDED

Environmental Component Affected	Most Recent Legislation	Objectives of Legislation	Types of Pollutants Considered	Approach and Requirements for Carrying Out Objectives
Solid Wastes	Resource Conservation and Recovery Act of 1976 PL 94-580	o Provide technical and financial assistance for the development of management plans and facilities for the recovery of energy and valuable materials from solid waste o Provide for the safe disposal of discarded materials o Regulate the management of hazardous wastes	o Solid waste-discarded material from industrial, commercial, mining, and agricultural operations and from community activities [1004 (27)] o Hazardous waste-solid waste or combination of solid wastes that may cause illness or pose a hazard to human health or the environment [1004(5)]	o State plans for disposal of nonhazardous wastes [4006] o Manifest system through which every load of hazardous waste material can be tracked from generation to ultimate disposal [3002(5)] o Permit program to cover every hazardous waste disposal site [3005]
Toxic and Hazardous Substances	Toxic Substances Control Act of 1976 PL 94-469	Regulate commerce and protect human health and the environment by requiring testing and use restrictions on certain chemical substances	Chemical substances or mixtures that present or will present an unreasonable risk of injury to health or the environment [6(a)]	o Testing of chemical substances and mixtures [4] o Notification to EPA of manufacture of new chemical or new use for a chemical [5] o Regulation of hazardous chemical substances [6]
Pesticides	Federal Pesticide Act of 1978 PL 95-396	To prevent unreasonable hazards to humans or the environment. (implicit)	Pesticides	o Registration of pesticides and producers o Classification for general use, restricted use, or denial of registration (unregistered pesticides may not be shipped, sold, or delivered) o Certification of users of restricted use pesticides

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[a] Numbers in brackets refer to Sections of applicable Acts.

[b] NRDC v. Train, No. 45-172, 8 ERC 2120, D.D.C., June 8, 1976.

standards are set at a level to protect public health, and secondary standards, to protect welfare.

Subsequently, NAAQS for particulate matter, sulfur oxides, carbon monoxide, photochemical oxidants,[22] hydrocarbons, and nitrogen oxides were promulgated by EPA, as required in the Act. Standards for lead were added later.

The 1970 Act mandated National Emission Standards for Hazardous Air Pollutants (NESHAPs), which have since been promulgated for asbestos, beryllium, mercury, and vinyl chloride. It also mandated New Source Performance Standards (NSPS) for new and modified industrial plants. These have been issued for 27 industrial categories, including industrial and electric utility boilers, smelters, and petroleum refining and storage.

The Clean Air Act Amendments of 1977 (PL 95-95) primarily modified existing programs rather than set new directions. The policy of prevention of significant deterioration (PSD) of air quality in clean air areas was made a detailed requirement of law rather than a generalized goal, as before. In areas that fall short of primary air quality standards (non-attainment areas), the law was modified slightly to allow some industrial growth, but only if reasonable further progress is made towards attainment of clean air. Auto emission standards were maintained, although they were somewhat modified and the deadlines were delayed by 2 or 3 years.

The 1977 Amendments reaffirmed the land use directions taken in the 1970 Act, via the new source review provisions for PSD and non-attainment areas, while dropping all express reference to "land use." The Act continues to have a major air quality management scheme, through the State Implementation Plans[23] and related permits, but it has also developed into a control technology statute, with Best Available Control Technology required in PSD areas and Lowest Achievable Emission Rate required in non-attainment areas.

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[22] The photochemical oxidants standard was later replaced by an ambient ozone standard. This should not be confused with protection of stratospheric ozone identified in Section 150 of the 1977 CAA Amendments.

[23] All states were required to revise their SIP's by July 1, 1979, to conform to the 1977 Amendments. By mid-September, 47 state plans had been submitted, but the sanction process against states whose plans are not approved is being exercised with restraint. EPA, "Environmental News," June 26, 1979.

Major Federal involvement continues and takes a new form, with growth and Federal funding restrictions in non-attainment areas, but state primacy is still present in many ways. Perhaps the most substantive deferral to the states is in the PSD program, wherein most clean areas start as Class II, but states can reclassify them to Class I (pristine) or Class III (the heaviest industrial development category) with only limited review by EPA.

Finally, the 1977 Act continues one of the most unusual features of the 1970 Act--the Congressional setting of numerical emission standards for automobiles, and even extends this concept to trucks.

Water Quality Legislation

The first major law applying to water was the Rivers and Harbors Act (or Refuse Act) of 1899, which prohibited solid discharges into navigable rivers and harbors. Initially designed to prevent obstruction of navigation, the Act was more recently interpreted as a general environmental law.

In 1948, the first comprehensive Federal legislation aimed specifically at water pollution control was passed. The Water Pollution Control Act (PL 80-845) authorized the Surgeon General to assist in formulation of state and interstate plans and uniform state laws; authorized research support; and permitted suits to be brought against polluters, with the state's consent.

These measures were made permanent in the Federal Water Pollution Control Act of 1956, which embodied the specifics of the 1948 Act. It also authorized planning, technical assistance, grants for state programs, and construction grants for municipal waste treatment facilities. Amendments in 1961 (PL 87-88) extended Federal enforcement authority to interstate, navigable intrastate, and coastal waters, and increased the funds authorized for construction grants. This interstate authority was to become the model for President Kennedy's clean air proposal of 1963.

In 1965, further amendments to the Water Pollution Control Act (PL 89-834) established the Federal Water Pollution Control Administration as successor to a program previously handled by the Public Health Service in the Department of Health, Education, and Welfare. The most important provisions in the 1965 Amendments called for the establishment of water quality standards and implementation plans for cleanup of all interstate and coastal waters. The states were designated as the primary enforcers of water quality standards.

In December 1970, President Nixon announced a new program to control water pollution from industrial sources through the permit authority of the Rivers and Harbors Act. To obtain permits, industrial dischargers had to disclose what and how much effluent they intended to discharge, thus providing a more exact indication of the nature and extent of industrial pollution.

Water pollution legislation took a different direction with the passage of the Federal Water Pollution Control Act Amendments of 1972. This Act extended Federal responsibilities to all U.S. waters, establishing effluent limitations for various classes of discharges, although the states still had implementation responsibilities. The Act's basic regulatory requirement is that point source dischargers--industries, municipal treatment plants, and feedlots--must obtain permits, must specify the quantity and composition of their effluents, and must establish schedules for achieving compliance. The Act marked a change from standards of ambient quality to effluent limits as the basis for achieving water quality. Also, identification of non-point sources of pollution was initiated under the area-wide waste treatment management plans, required by Section 208. The Act also set deadlines: 1977 for best practicable treatment (BPT), and 1983 for best available technology (BAT); and it set goals: fishable, swimmable waters by 1983, and zero discharge by 1985.

The Clean Water Act of 1977 (PL 95-217) modified the cleanup deadlines of the 1972 Amendments, identified several new categories of pollutants, and provided for establishment of new technology-based standards. For controlling "conventional" pollutants (biological oxygen demand (BOD), suspended solids, fecal coliform, and pH), the Clean Water Act requires "best conventional pollutant control technology." For controlling toxic pollutants, it requires "best available technology economically achievable."[24] Both are required by July 1, 1984. Under the Act, "nonconventional" pollutants that are neither toxic nor "conventional," such as chemical oxygen demand, dissolved solids, or oil and grease, must meet EPA-issued effluent guidelines by July 1, 1987. This Act also authorizes additional regulations to require best management practices (BMP) to reduce surface runoff from plant operations, although it does not directly regulate non-point sources.

Under the Clean Water Act, point source discharges are subject to both Federal and state regulations. States with qualified programs can take over the permit program of the National Pollutant Discharge Elimination System (NPDES), as 32 states have done. New

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[24] An initial list of 65 toxic pollutants and classes of pollutants derives from a 1976 settlement in U.S. District Court (D.C. Circuit) in the case of NRDC v. Train. See Chapter 11 (11.2.4) for an expanded discussion.

Source Performance Standards have been issued for 31 industrial categories. These standards define the level of pollution control required for new plants and require the greatest degree of effluent reduction achievable through use of the best available control technology. The NSPS are applied to individual plants through issuance of NPDES permits.

EPA may grant waivers of Best Available Control Technology (BACT) for nonconventional pollutants, but not for toxic substances, if an industry shows that: (1) the best practicable control technology standards will be met; (2) the waiver will not result in any additional requirements on any other point or non-point source; and (3) the waiver will not interfere with the attainment or maintenance of fishable, swimmable water quality.

Solid Waste Legislation

Primary responsibility for solid waste disposal has traditionally been vested in local authorities. In 1965, the Federal government assumed a significant supporting role with the passage of the Solid Waste Disposal Act (PL 89-272). This Act sought to conserve natural resources by reducing waste and unsalvageable materials and by solid waste recovery. Under this Act, the Federal government is responsible for research, training, demonstrations of new technology, technical assistance, and grants for solid waste planning programs.

In 1976, the Federal government's role was amplified with passage of the Resource Conservation and Recovery Act (RCRA) (PL 94-580). This Act promotes resource recovery and conservation, and mandates a system of manifests to ensure Federal government control of hazardous waste, from generation to final disposal in facilities for which permits are issued. The Act requires a Federal or equivalent state regulatory, inspection, and enforcement program in every state.

The Act directs the Administrator to set criteria for identifying and listing hazardous wastes and for setting standards applicable to generators, transporters, and disposers of hazardous wastes. Each person owning or operating a facility to treat, store, or dispose of hazardous wastes must have a permit to operate. Resource recovery and waste reduction are indirectly affected, since cheap disposal options will no longer be available. Federal assistance is an incentive for states to adopt adequate programs. If a state fails to enact a program, the law empowers EPA to promulgate one.

Regulations for implementing the Resource Conservation and Recovery Act are now being prepared; hence, experience with the Act and knowledge of its results thus far are limited.

Toxic Substances Legislation

Enactment of the Toxic Substances Control Act (TSCA) (PL 94-469) in 1976 empowered the Federal government, for the first time, to control the production and use of chemical substances that may present an unreasonable risk of injury to health or the environment. Under this Act, manufacturers may be required to test chemicals or report production details and physical, chemical, and biological properties. Recordkeeping and disclosure of health effect information are required. In addition, the Federal government now has the authority to regulate potentially dangerous chemicals and take immediate action to prevent their commercial distribution, if they are found to represent an unreasonable risk.

Implementation of TSCA is in early stages, with Federal interagency coordination delegated to two committees--the Toxic Substances Strategy Committee, concerned with appropriate application of all laws relating to toxic substances, and the Interagency Testing Committee, responsible for recommending to EPA substances that should be tested for potential hazards.

Pesticide Legislation

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1947 (PL 80-104) and subsequent amendments through 1964 directed the Secretary of Agriculture to control the labeling of, and to register, all pesticides destined for interstate distribution or sale.

In 1972, the Federal Environmental Pesticide Control Act (PL 92-516) extended Federal authority to the use of pesticides, authorized classification of chemicals for restricted use by trained applicators only, and extended controls to products sold only in intrastate commerce, as well as those sold in interstate commerce. Administrative procedures added in 1975 amendments require that EPA allow the Secretary of Agriculture and a scientific advisory panel opportunity to comment before EPA cancels a registration or changes a pesticide classification.

The Federal Pesticide Act of 1978 requires re-registration of all pesticides. It also was designed to simplify the registration process, replacing the previous one-by-one approach with a program to regulate directly the 1,400 active chemical ingredients that are used in pesticide products. All pesticides sold, shipped, delivered, or received in the United States must be registered with EPA. Establishments that produce pesticides also must be registered with EPA.

Energy Legislation

Since the OPEC embargo of 1973, the enactment of energy-related laws has increased sharply. Most of this legislation affects existing environmental legislation, and several laws refer specifically to the Clean Air and the Resource Conservation and Recovery Acts.

One theme in energy legislation is conservation. One approach is to reduce energy demand (and consumption); another is to shift from fuels in short supply (e.g., petroleum) to more abundant and domestically available resources (e.g., coal). Reducing demand should mitigate adverse environmental effects. However, using alternative energy supplies may place burdens on the environment at the points of production, distribution, and consumption.

The Energy Supply and Environmental Coordination Act of 1974 (ESECA) (PL 93-319) allowed the Federal Energy Administration (predecessor to the Department of Energy) to prohibit any power plant or major fuel-burning installation from burning natural gas or petroleum products as its primary energy source if it has the capability and equipment to burn coal. Additional incentive to burn coal is found in the Energy Policy and Conservation Act of 1975 (EPCA) (PL 94-163), the Energy Tax Act of 1978 (PL 95-618), and the Power Plant and Industrial Fuel Use Act of 1978 (PL 95-620), which continued and extended the regulatory thrust started by the ESECA. Significantly, in all cases, the switch to coal must be consistent with applicable environmental requirements. EPCA also set automobile fuel economy standards, which were seen as consistent with the requirements of the Clean Air Act.

Other laws with significant conservation sections are the Energy Conservation and Production Act of 1976 (PL 94-385), the Resource Conservation and Recovery Act, and the National Energy Conservation Policy Act of 1978 (NECPA) (PL 95-619). The last two Acts illustrate that environmental and energy legislation may be complementary. RCRA mandates the study of recovering energy from solid wastes; NECPA mandates the establishment of targets for increased industrial utilization of recovered materials.

Another theme of energy legislation has been the development of new energy technologies. Examples are the Solar Heating and Cooling Demonstration Act (PL 93-409), the Geothermal Energy Research, Development, and Demonstration Act (PL 93-410), the Solar Energy Research, Development, and Demonstration Act (PL 93-473), and the Federal Non-Nuclear Energy Research and Development Act (PL 93-577), all enacted in 1974. In the last Act, Section 11 has particular environmental significance; this section directed the Council on Environmental Quality to assess, on a continuing basis, the adequacy of attention to environmental protection in Federal non-nuclear research, development, and demonstration programs. Public hearings on "the probable consequences of trends in the development and application of energy technologies" are also required. The Executive Reorganization Plan of 1977 transferred responsibility for Section 11 from CEQ to EPA.

3.4.4 Comparisons of Legislative Approaches

Many of the differences in approaches to the control of environmental pollutants are related to the types of substances regulated--residuals from industrial processes, energy production, and waste treatment systems under the Clean Air Act, the Clean Water Act, and the Resource Conservation and Recovery Act, and the products themselves under the Toxic Substances Control Act and the Federal Insecticide, Fungicide, and Rodenticide Act.

The Clean Air Act and the Clean Water Act require technology-based levels of emission control and include ambient air and water quality standards. They often lead to "end-of-the-pipe" controls to eliminate hazards to human health and to the environment following processing, although they also have substantial land use implications. For example, the prevention of significant deterioration provision in the Clean Air Act is a major consideration in siting decisions.

The Resource Conservation and Recovery Act set up a system for the management of pollutants rather than prescribing the level of pollutants to be attained in any medium. However, the standards for management must be sufficient to protect human health and the environment, a test that is similar to those used in setting ambient and effluent standards under the other Acts. This Act mandates no changes in technology, although it authorizes research and technological evaluation of disposal and resource recovery methods. Rather, it requires the issuing of permits to those operating hazardous waste handling facilities. It also requires recordkeeping by means of a manifest system. No pollutant is specifically mentioned. In contrast, both the Clean Air and Clean Water Acts mention several specific pollutants, and the Toxic Substances Control Act regulates disposal of certain substances (e.g., polychlorinated biphenyls).

TSCA and FIFRA control the testing, production, and use of hazardous and toxic products through regulations. As with RCRA, no standards are promulgated in these Acts, no specific levels of pollutants in the environment are mandated, and no pollution control technology requirements are specified.

All these Acts are enforced through a combination of civil and criminal penalties, including compliance and prohibition orders, fines, and imprisonment. Compliance orders, requiring that persons or states comply with the requirements of the Acts, and prohibition orders, requiring cessation of actions not in accordance with the Acts, are the most commonly used enforcement tools. EPA can bring suit to force individual companies to comply with the provisions of the Acts. An economic enforcement tool was recently provided in Section 120 of the Clean Air Act, which provides for civil non-compliance penalties, to be set at a level which prevents a company from gaining a competitive advantage by non-compliance.

Cost of compliance is not considered uniformly in the various Acts. In the Clean Air Act, for instance, the application of "best available control technology" takes into account "...energy, environmental, and economic impacts and other costs" (Section 169[3]). The application of "lowest achievable emission rate" does not explicitly consider economics, but allowing new sources to be built at all in a non-attainment area is an indirect concession to economic considerations. The Resource Conservation and Recovery Act requires financial problems to be considered in formulating state solid waste plans, but does not explicitly consider costs in the case of hazardous wastes. In the Clean Water Act, the "best available technology economically achievable" requirement for toxic pollutants implies cost considerations. However, both Acts that deal with products--TSCA and FIFRA--contain provisions explicitly requiring consideration of costs.

3.4.5 Recent Trends

Environmental regulations, like other regulations, are often complex. They may lead to increased costs, but as often they lead to internalization rather than externalization of costs. Energy-economic-environmental conflicts are frequently present. As the following brief discussion indicates, both a trend towards increased complexity of regulations and a movement towards reform are increasingly evident.

Amendments have made long-established environmental laws more complex. Recent amendments to both the Clean Water and Clean Air Acts have identified new sources of pollutants and have required effluent limitations for particular categories of industries. Including a list of toxic pollutants (interpreted as 129 pollutants) in Section 307 of the 1977 Amendments to the Clean Water Act, has greatly increased the complexity of that Act.[25] For each pollutant listed, unless a more stringent standard is set, the best available technology economically achievable is to be applied.

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[25] See Chapter 11, Section 11.2.4.

In the newer regulatory acts, requirements for hazardous and toxic products have led to problems in defining risk and in quantifying "acceptable" risk. TSCA gives EPA authority to take action to prevent any unreasonable risk of injury to health or the environment; however, "unreasonable risk" is difficult to define.

A far-reaching effect of attempts to regulate pollutants has been the distinction between EPA as the provider of proof of toxicity for the residuals, and product proponents as providers of proof of product safety. This division of emphasis has placed most of the costs for demonstrating risk on the Federal government for residuals, and on specific industries for products.

Regulatory reform to minimize costs and delays, while ensuring protection of public health and the environment, is the subject of increasing efforts. President Ford, in Executive Order 11821 of November 1974, directed that "inflation impact statements" be issued for all major executive agency legislative proposals and regulations. In March 1978, President Carter signed Executive Order 12044, which required agencies to prepare a regulatory analysis for those regulations with major economic consequences, and further directed agencies to publish, at least semiannually, an agenda of significant regulations under development or review.

A number of committees for regulatory coordination or review have recently been formed within the Executive Branch. The first was the 17-agency Toxic Substances Strategy Committee formed in response to the directive in President Carter's 1977 Environmental Message to coordinate Federal regulatory activities concerning toxic chemicals.[26]

The Interagency Regulatory Liaison Group was formed on September 26, 1977, by interagency agreement among the Environmental Protection Agency, Food and Drug Administration, Consumer Product Safety Commission, and Occupational Safety and Health Administration (42 FR 54856). Related agencies of USDA recently joined the IRLG. The group is principally concerned with achieving consistent regulatory policy and efficiently using resources in the regulation of toxic and hazardous substances.

The Regulatory Analysis Review Group, formed in 1978, is led by the Council of Economic Advisers, and reviews the regulatory analyses prepared by the agencies under Executive Order 12044.

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[26] Carter, J., Message to the Congress of the United States, The White House, May 23, 1977.

The Federal Regulatory Council was created following President Carter's inflation message of October 1978 and is currently chaired by the EPA Administrator. The President's goal for the Council is to combat inflation by monitoring regulatory agency rules to help hold down costs, to reduce Federal paperwork, and to prevent overlapping and duplication of Federal regulations.

Thus, the current trend within the Executive Branch is continued support for environmental protection, coupled with increased regulatory review and reform. The aim is to decrease the cost and complexity of regulation without sacrificing the environmental protection mandated by legislation.

3.4.6 Future Directions

It seems likely that Federal legislative actions in the future will respond to the tightening energy supply and to the effects of complete implementation of the Resource Conservation and Recovery Act.

The President's mandate of July 1979 to hold foreign oil imports to the 1977 level and the magnitude of his proposed program for accelerated synthetic fuels commercialization demonstrate the potential for conflict between energy and environmental policies, which, as noted earlier, the public now recognizes.[27] However, President Carter's message on the environment (August 2, 1979) assures that environmental protection will be built into the synfuels development process and that trade-offs will be made fairly, equitably, and in the light of informed public scrutiny.[28] For example, the Administration's proposal for an Energy Mobilization Board is designed to speed up, not circumvent, the environmental review process mandated by the National Environmental Policy Act.

Future legislation is not expected to weaken current environmental programs. Rather, it seems more likely that legislation will aim toward careful structuring of emergency responses and expediting actions mandated or permitted under current laws. For example, statutory authority for emergency suspension of environmental plans, such as that found in Section 110(f) of the Clean Air Act, has been carefully worded to fulfill specific environmental needs. Thus, in light of the President's pledges; the Congress's continuing deference to strong environmental laws, as demonstrated by recent energy legislation; and the public's strong, well-established support of the environment, it appears that the U.S. environment will at least maintain its currently protected status.

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[27] Carter, J., Address to the Nation, July 15, 1979.

[28] Carter, J., Message to the Congress of the United States, The White House, August 2, 1979.

The effects of implementation of the Resource Conservation and Recovery Act are already being felt across the country. The Act's criteria for solid waste disposal and hazardous waste management make for much higher disposal costs. They also point up the limited availability of suitable disposal sites. Previously, minimal solid waste disposal programs required only a remote plot of land and a tractor. Today, land, particularly near urban areas, is less readily available and more expensive. As costs mount and progress is made in resource recovery research and development, commercial resource recovery should become more economically attractive.

3.5 INTERNATIONAL DEVELOPMENTS

3.5.1 Trends in Other Countries

Although a country-by-country examination of governmental environmental action is beyond the scope of this chapter, several general international environmental trends are apparent.

- Governments are institutionalizing environmental programs.

- Both developed and developing countries have established or are establishing centralized environmental agencies or ministries. This trend may be in response to the need to define and regulate internal environmental problems or to deal with the problems and opportunities afforded by intergovernmental activities. The successful operation of the United Nations Environmental Program's information network and the International Register of Potentially Toxic Chemicals may well require considerable government involvement.

- Developed countries are making progress in controlling pollution-related environmental problems, particularly point-source air and water pollution.

- The overriding environmental problems in many underdeveloped nations arise from rapid population growth and urbanization, and government policies that often promote "industrialization at any cost."

Activities in the developed countries often resemble those in the United States, but different types of regulatory initiatives have been applied. For example, since 1973, legislation in both Japan and the German Democratic Republic has authorized charges on the discharge of pollutants.[29] The "let the polluter pay" approach to pollution control is one of the 10 environmental recommendations made by the Organization for Economic Cooperation and Development (OECD).[30]

In countries such as India, Nepal, and Haiti, the immediate food and fuel needs of burgeoning populations have resulted in massive deforestation, the use of animal wastes for fuel instead of fertilizer, and the reduction or elimination of fallow periods in the farming cycle. These in turn have caused erosion, degraded water quality, changed rainfall patterns, loss of soil productivity, and reduction of local food supply. Thus for many developing countries, meeting basic immediate human needs while providing adequate environmental protection for the longer term poses a dilemma. To a country facing this dilemma, discussions of long-range problems like global carbon dioxide production or destruction of the ozone layer hardly seem relevant.

3.5.2 International Dimensions of Environmental Issues

International environmental activity parallels that of the United States, and the trend is for more activities by more organizations. Early concerns focused on agricultural resources and public health. Early health organizations were the Pan American Sanitary Bureau (1902), the International Office of Public Health (1909), and the Health Organization of the League of Nations (1923).

The United Nations quickly assumed a central environmental role through its Food and Agricultural Organization (1945) and World Health Organization (1948). A unified United Nations environmental program was envisioned soon after the 1968 Swedish proposal to consider the human environment.[31] In December 1972, the United Nations Environmental Program (UNEP) was created by General Assembly resolution,[32] in response to the Declaration on the Human Environment issued in Stockholm in June 1972.

Several other international organizations are also actively addressing environmental concerns. These groups are discussed in the following sections.

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[29] "A New Strategy for Environmental Control," Resources, Vol. 59, April-July 1978, p. 2.

[30] Organization for Economic Cooperation and Development, Meeting of the Environment Committee at Ministerial Level, November 1974, Recommendation C(74) 223.

[31] Caldwell, L.K., Environment: A Challenge to Modern Society, Anchor Books, Garden City, New Jersey, 1970, p. 98.

[32] United Nations General Assembly Resolution 2997 (XXVII).

The United Nations Environment Program (UNEP)

UNEP was created to catalyze environmental concern within U.N. agencies, including development assistance banks, and to coordinate efforts by member countries to cooperate in protecting the global commons and resolving transnational issues. Limitations in the Environment Fund, the fund from which UNEP's appropriations are drawn, have allowed for little expansion of function, although occasional projects have been funded to fill gaps in environmental knowledge. All annual UNEP program appropriations over the 1978-1981 period are approximately equal to each other, with 1980 authorized at $31.5 million.[33] This figure is less than 10 percent of EPA's FY 1979 appropriation for research and development alone.

UNEP's environmental program covers many subject areas and functional tasks that indicate the diverse environmental concerns of developed and developing countries. Several program goals addressing regional concerns or environmental problems of a broad range of countries have been met expeditiously. For example, the Intergovernmental Meeting on the Protection of the Mediterranean, convened by UNEP in 1975, has resulted in treaties and protocols, coordinated research, and integrated planning; and the 1977 United Nations Conference on Desertification drafted an action plan that is being implemented.

Concerns of either developed or developing nations alone have been addressed less successfully. Earthwatch, the environmental assessment task identified in the 1972 action plan, has not developed mechanisms or funding for assessment; UN Habitat and Human Settlements Foundation (1974) and Habitat, Centre for Human Settlements (1977), major interests of developing countries, have received few governmental contributions.

Atmospheric problems such as carbon dioxide, stratospheric ozone, and acid rain (see Chapter 5) may define significantly "the outer limits" of global environmental health that Earthwatch was created to assess. An operational Earthwatch with a fully implemented Global Environmental Monitoring System may be necessary before meaningful global environmental assessments can be made. Recommendations for mechanisms and procedures for conducting environmental assessment within Earthwatch will be on the agenda of the UNEP Governing Council's 1980 session.[34]

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[33] Personal communication, Francis X. Cunningham, U.S. Department of State, July 1979.

[34] Mainland, E., Memorandum, U.S. Department of State, June 12, 1979.

Organization for Economic Cooperation and Development (OECD)

The Council of OECD, an organization of 25 developed nations, established the Environment Committee in 1970. The Environment Committee meeting at Ministerial level in November 1974 adopted 10 recommendations that have served as elements of the environmental agenda for member countries and an action plan for the Environment Committee.[35] The activities of the Environmental Directorate were funded at a level of 9.35 million French francs ($2.15 million) for 1978.[36] EPA Administrator Douglas Costle chaired the Ministerial Level Meeting in May 1979, at which new emphasis was put on anticipatory environmental policies, improved technologies and practices for coal combustion, improved economic analysis of environmental benefits and cost, and improved environmental reporting.

Economic Commission for Europe (ECE)

Both eastern and western European nations are members of the Economic Commission for Europe. EPA Administrator Costle chaired the U.S. delegation to the ECE High Level Meeting on the Environment, held in Geneva November 13-16, 1979. He was one of the signatories of the international convention on long-range transportation of air pollutants. While not binding, the convention provides that ECE member nations will take appropriate measures both nationally and internationally to abate or eliminate transboundary air pollution.

Organization of American States (OAS)

The Organization of American States has a modest program in environmental sciences and ecology that generally funds small projects. Occasionally, larger projects (more than $1 million) are supported, such as a recent study of development in arid and semiarid lands in Argentina. OAS also sponsors regional meetings on such topics as marine mammals, migratory animals, and terrestrial ecosystems.

International Bank for Reconstruction and Development (World Bank)

The World Bank provides loans and technical assistance for projects in developing countries. The Bank's Office of Environmental and Health Affairs was created in 1970 to identify and mitigate adverse environmental effects of development projects. The Bank has funded environmental studies, and loan conditions may require environmental controls. Since loans total billions of dollars annually ($8.7 billion by the Bank and its affiliates in FY 1978),[37] the World Bank could be a significant environmental influence in the developing nations.

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[35] Organization for Economic Cooperation and Development, Meeting of the Environment Committee at Ministerial Level, November 1974, Recommendations C(74)215-224.

[36] Personal communication, Leigh Morse, U.S. Department of State, July 1979.

Committee on the Challenges of Modern Society

This Committee, established under NATO in 1969, encourages voluntary participation in non-defense-oriented international projects. EPA is the lead agency for four current environmental pilot studies--flue gas desulfurization, drinking water, estuarine management, and plastic wastes recovery.

Bilateral Agreements

Finally, and perhaps most significantly for research and development, there are numerous bilateral intergovernmental agreements. Some, such as the Boundary Waters Treaty of 1909 between the United States and Canada that established the International Joint Commission, have been of significant long-term import. There are many other agreements, some of them long-range umbrella agreements and others short-term project agreements focused on specific topics.

3.6 CONCLUSIONS

The quick survey of societal trends in this chapter supports the general conclusion that protecting the environment is a widely shared objective. This seems to be the case both internationally and nationally. It appears to be the case regardless of the indicator used, whether it be public opinion, legislation, or the proliferation of organizations. Obviously, the future environmental outlook depends largely on whether protecting the environment continues to have a high priority among the competing values which must be accommodated when public policies are made. For this reason, future Environmental Outlook reports will attempt to deal more explicitly and extensively with likely changes in values in the future, and what these changes might mean.

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[37] World Bank, World Bank Annual Report 1978, p. 9.

CHAPTER 4
AIR POLLUTANTS

HIGHLIGHTS OF CHAPTER 4

- Between 1975 and 2000, emissions of hydrocarbons and carbon monoxide are expected to be reduced significantly, with particulate emissions decreasing to a lesser extent. These reductions, which assume full compliance with existing pollution control regulations, should be of particular benefit to urban areas. However, emissions of nitrogen oxides are projected to increase during the projection period under high economic growth conditions, and sulfur oxide emissions are projected to remain relatively constant. In some regions, this could aggravate problems of acid precipitation and photochemical smog.

- Although gross generation of particulates is expected to double between 1975 and 2000, net emissions are expected to decrease slightly during the period.* When inhaled, particulates can contribute to respiratory disorders. The construction materials industry, which is the major source of particulate emissions, is the only industrial source for which net emissions are forecast to increase; the most substantial decrease occurs in the steel industry.

- Net emissions of sulfur oxides, which may affect lung function, are projected to remain relatively constant between 1975 and 2000. Coal combustion by electric utilities and industrial boilers accounted for two-thirds of net sulfur oxide emissions in 1975. Although coal use by these sectors is expected to double by 2000, net sulfur oxide emissions are expected to remain relatively constant as a result of the application of flue gas desulfurization techniques.

- Nitrogen oxides can have adverse effects on the human respiratory system, and their presence in the atmosphere contributes to photochemical smog and acid precipitation. Growth in electric power generation and industrial combustion between 1975 and 2000 is projected to be the major source of increasing net emissions. Increases from these and other sources should be partially offset by decreases in emissions due to controls for motor vehicles.

- Hydrocarbons are a significant air quality problem because they contribute to the formation of photochemical oxidants. In 1975,

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*See section 2.4 for definition of "gross" generation of pollutants and "net" emission of pollutants.

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over three-fourths of the urban counties in the U.S. failed to comply with primary ambient air quality standards for photochemical oxidants.

- Net carbon monoxide emissions are projected to be halved between 1975 and 2000, primarily because of reduced transportation emissions. Carbon monoxide is believed to cause cardiovascular disease symptoms and other adverse health effects. Carbon monoxide may be transformed in the atmosphere into carbon dioxide which is not regulated, but which may have adverse long-range effects on climate. Total net emissions of hydrocarbons are expected to decrease between 1975 and 2000 mainly because of the control of emissions from mobile sources.

- There has been increasing concern regarding emissions of lead and other toxic substances due to the adverse health effects of exposure to these elements. Lead emissions are expected to decline greatly in the future because of reductions in lead fuel additives. In contrast, emissions are expected to increase for substances such as cadmium, nickel, selenium, arsenic, fluorine and antimony.

4.1 INTRODUCTION

4.1.1 Problem Definition and Regulatory Background

Over the past two decades, Americans have become increasingly aware of the deleterious effects of air pollution on human health, visibility, climate, plants, and animals. In response to public concern over deteriorating air quality, Congress passed the Clean Air Act in 1963. Since then, additional laws have been passed to reinforce the 1963 Act. The Air Quality Act of 1967 and the Clean Air Act Amendments of 1970 and 1977 established a number of regulatory mechanisms (summarized in Table 4-1) for controlling emissions from "stationary" (e.g., industrial plants, utilities) and "mobile" sources of major air pollutants.

Air pollution regulations, although stated in terms of abatement of emissions at their sources, are designed ultimately to achieve federally-mandated standards of ambient air quality set at levels that protect public health and welfare. Standards have been established for the permissible ambient concentrations of seven atmospheric pollutants--particulates, sulfur oxides (SO_x), nitrogen oxides (NO_x), hydrocarbons (HC), carbon monoxide (CO), ozone (O_3) and lead. The 1977 Clean Air Act Amendments require periodic review of ambient standards. Review will include reexamination of available control technologies and analysis of whether additional airborne pollutant categories (e.g., fine particulates, sulfates) need to be controlled.

TABLE 4-1
MAJOR REGULATORY MECHANISMS FOR AIR POLLUTION CONTROL

Regulatory Mechanism	Legislative Source of Mechanism	Scope of Regulation	Pollutants Regulated	Sources Affected	Summary Description of Regulation
State Implementation Plan (SIP)	1970 Clean Air Act Amendments (PL.91-604)	State	All criteria pollutants	Stationary	For existing (pre-1971)[a] industrial and electric utility facilities, sets limits on emissions as part of a statewide plan to reduce ambient concentrations of criteria pollutants.
New Source Performance Standards (NSPS)	1970 Clean Air Act Amendments	National	All criteria pollutants	Stationary	Requires new facilities in selected industries to meet national emission standards for criteria pollutants.
Revised New Source Performance Standards	1977 Clean Air Act Amendments (PL 95-95)	National	All criteria pollutants	Stationary	Provides new and stricter emission standards for criteria pollutants reflecting the degree of control that can be achieved by Best Available Technologies (BACT).

(Continued)

TABLE 4-1 CONTINUED

Regulatory Mechanism	Legislative Source of Mechanism	Scope of Regulation	Pollutants Regulated	Sources Affected	Summary Description of Regulation
Mobile Source Emission Standards	1970 Clean Air Act Amendments	National and Local	Nitrogen Oxides, Hydrocarbons, Carbon Monoxide, Photochemical Oxidants	Mobile	Requires automobile and truck manufacturers to produce vehicles meeting standards that are made more stringent over time.
Offset Requirements	1977 Clean Air Act Amendments	County	All criteria pollutants	Stationary and Mobile	In areas violating primary and secondary National Ambient Air Quality Standards (NAAQS), requires sources to identify and implement methods to more than "offset" emission increases by reducing emissions from sources already in the area.
Prevention of Significant Deterioration (PSD) Requirements	1977 Clean Air Act Amendents	County or portion of county	Particulates (TSP) Sulfur Dioxide	Stationary and Mobile	In areas that meet NAAQS, strictly regulates increases in ambient pollution levels in order to prevent any significant deterioration of air quality.

(Continued)

TABLE 4-1 CONCLUDED

Regulatory Mechanism	Legislative Source of Mechanism	Scope of Regulation	Pollutants Regulated	Sources Affected	Summary Description of Regulation
National Emission Standards for Hazardous Air Pollutants	1970 Clean Air Act Amendments	National	Beryllium Asbestos Mercury Vinyl Chloride	Stationary and Mobile	Provides emission standards for hazardous air pollutants that are not regulated by ambient air quality standards.

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[a] Subpart D of 40 CFR 60 establishes emission standards for industrial and electrical utility plants constructed or modified after 1971; plants already existing as of 1971 are regulated at state level. In this chapter the terms old (pre-1976) plants and new plants have been used to make the distinction between the two levels of regulation, since in the SEAS model construction of a new plant is assumed to require four years.

The trend projections discussed in this chapter reflect the simplifying assumption that no changes will be made to the standards in effect as of July 1, 1978. Even as EPA research reveals new environmental problems likely to require more stringent control, concerns over energy availability or economic growth are producing pressures toward relaxation of environmental standards. Given these countervailing influences, the future direction of environmental regulation is impossible to forecast, and it is most prudent in making projections to assume that no significant net changes will occur.

The air pollution trend analyses presented in this chapter provide projections of both "gross" emissions and "net" emissions. The terms gross generation and gross pollution refer to the amount of pollutant that is generated prior to the benefit of any abatement devices including abatement equipment already in place in 1975.[1] Net emissions represent pollutants actually released to the atmosphere after all legally required abatement has been achieved.

Thus, the net emissions levels reported here would be achieved only if all sources were to comply fully with all abatement regulations in effect July 1, 1978. Full compliance should be understood to mean the installation of required control systems and the sustained performance of these systems at design control efficiency. Perfect attainment is not expected; indeed, recent EPA research indicates that emissions from both stationary and mobile sources often greatly exceed the intended standards, even in cases where the source has been officially identified as being in compliance.[2] When interpreting the trends and graphic representations of air emissions presented here, the reader should remember that actual air emissions for a given scenario would probably fall somewhere in the range between the projections of gross generation, as a maximum, and net emissions, as a minimum. We recognize, therefore, that the "net emissions" projected in the SEAS model certainly underestimate actual emissions to some degree.

In addition, SEAS does not account for indoor sources of air pollutants. Sources such as tobacco smoking, indoor cooking and heating equipment, and building materials are under investigation from a public health standpoint. This research is being conducted by the EPA in cooperation with other Federal agencies under the authority of the Public Health Service Act (PL 956 23-Title 3-Section 304). Although indoor sources may not be significant when compared to total emissions of a given pollutant, they may be very important in terms of health consequences.

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[1] Although most environmental policies are not directed toward reducing the level of gross generation in future years, gross generation will be indirectly influenced by process or material input substitutions made by industry over time in response to economic stimuli, such as rising energy prices.

[2] Korb, B.R. et al., Review of EPA's Emission Control Program for Light Duty Vehicles, draft report, December 1977.

4.1.2 Relevant Scenario Assumptions

The future levels and regional distribution of air pollutant emissions are particularly sensitive to four of the scenario assumptions described in Chapter 2 of this report. These assumptions are described in Table 4-2. In general, forecasts of air emissions will be most affected by policies influencing the levels of energy consumption by industrial and private users, the mix of fuels being consumed, and consumer preferences toward transportation or siting alternatives.

It must be remembered that the projections we have derived on the basis of the High and Low Growth Scenarios are intended only as trend indicators, not as predictions of the future. Their purpose is to indicate the direction of change in certain parameters of environmental quality, given current policies and a range of conceivable economic futures. As such, they permit us to identify the implications for the future of our present environmental policies.

4.1.3 Data Sources and Quality

Environmental Protection Agency documents are the principal sources for emissions data used in these analyses.[3] These sources provide a compilation of human activities that contribute to air pollution. Data for some pollutant categories, such as fine particulates and indoor pollutants, are scarce or non-existent. Much of this information was published in 1975 and 1976. However, emissions estimates for energy consumption activities such as electricity generation, industrial fuel combustion, and highway transportation

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[3] These sources include, among others: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Compilation of Air Pollution Emission Factors, Publication AP-42, and Supplements 5-8, March 1975; Massaglia, M.F., Summary of Particulate and Sulfur Oxide Source Categories, 1970-1975, Vol. II, Research Triangle Institute, Research Triangle Park, North Carolina, August 1976; Battelle Columbus Laboratories, "Cost of Clean Air and Water: 1976-1985," unpublished technical report, April 1977.

TABLE 4-2
MAJOR ASSUMPTIONS AFFECTING PROJECTIONS OF FUTURE LEVELS AND DISTRIBUTION OF AIR POLLUTANT EMISSIONS

Major Assumptions	Description
Substitution of Coal for Oil and Gas	Emissions from fuel combustion, especially coal burning, are a significant portion of particulate, sulfur oxide, and nitrogen oxide emissions from human activities. Thus, increased use of coal as a utility and boiler fuel will tend to offset environmental improvements from implementation of environmental controls.
Rate at Which Existing Electric Utilities are Phased Out and Replaced by New Facilities	Under current SIP requirements, older electric utilities (existing before 1976) are generally permitted much higher pollutant releases per unit of electricity generated than are new facilities. To simulate the effect of slower economic growth on the availability of investment capital for plant expansion, the rate at which older facilities are replaced is lower in the Low Growth Scenario than in the High.
Effect of Economic Growth on Transportation Activity	Low economic growth, high oil prices, and shifts among transportation modes tend to reduce transportation activity and the emissions from vehicular travel (e.g., NO_x, hydrocarbons, carbon monoxide).
Energy Development and Population and Industrial Shifts	Energy development in the West and Southwest, along with a gradual shift in population and industrial activity to the "Sunbelt" states, will affect the regional distribution of emissions over time.

have been periodically updated and refined over the last two years.[4]

Because of the prominence of combustion and transportation as air pollution sources, specialized detailed approaches are used to calculate pollutants from these sources. Pollutants from electric utilities and industrial combustion activities are calculated separately for those facilities in operation before 1976 and those on-line later, in order to reflect the differences in stringency among the applicable emission limitations.[5] Mobile source emissions are calculated on the basis of estimates of the age distribution, mileage, and occupancy of the motor vehicle fleet over time, in conjunction with a set of emission factors for each model-year vehicle. This level of detail substantially improves the model's capability to project general air emission trends at the national or Federal Region level. However, SEAS does not simulate the regulatory environment, which will strongly affect construction of new industrial facilities in non-attainment and Prevention of Significant Deterioration (PSD) areas.

In an attempt to evaluate the quality of the emissions data base for most air pollutants estimated by SEAS, the SEAS values for 1975 have been compared with estimates made for 1973 by EPA's National Emissions Data System (NEDS).[6] The NEDS data base contains a source-by-source inventory of emissions which is periodically updated by EPA. The SEAS data base utilizes some information from NEDS, but makes use of many other data sources, including the Major Fuel Burning Installation data base, Federal Power Commission power plant inventories, and information gathered by Battelle for the Cost of Clean Air report. Comparisons of NEDS to SEAS are useful for determining discrepancies which may indicate potential weaknesses in SEAS or NEDS coverage of major sources of pollution. The comparisons are presented within the introductory discussion on each pollutant.

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[4] Data sources used in updating the residuals data base include: U.S. Environmental Protection Agency, State Implementation Plans - Emission Regulations for Particulate Matter: Fuel Combustion, August 1976, and State Implementation Plans - Emission Regulations for Sulfur Oxide: Fuel Combustion, September 1978. Both studies were done for the EPA Office of Air Quality Planning and Standards, Office of Air and Waste Management. Also Dux, D.D. et al., Modeling Long-Term Coal Production with the Argonne Coal Market Model, Argonne National Laboratory, August 1977.

[5] Emission standards for industrial combustors and public utility plants constructed or modified after 1971 are set by Federal regulation (New Source Performance Standards); plants already existing as of 1971 are regulated at state level (State Implementation Plans). In this chapter, the terms "old (pre-1976) plants" and "new plants" are assumed to make the distinction between the two levels of regulation (SEAS assumes that construction of a new plant requires five years).

[6] U.S. Environmental Protection Agency, 1973 National Emissions Report, National Emissions Data System of the Aerometric Emissions Reporting System, EPA-450/2-76-007, May 1976.

Overall, there generally is a close correspondence between these data sources for the 1975 estimates of TSP, SO_x, NO_x, and CO emissions. In future years, confidence levels are greatest for TSP and SO_x. The trend in NO_x estimates may change dramatically if additional control requirements are established. In addition, projections of NO_x, HC, and CO are probably understated due to the assumption that mobile sources will fully comply with current standards. More recent NEDS data (for 1975), which have been published recently, were not available at the time of this analysis.

4.1.4 Organization of Chapter

The remainder of this chapter is organized into seven sections. In Sections 4.2 through 4.6, SEAS emission projections are presented for five major air pollutants--particulates, sulfur oxides, nitrogen oxides, hydrocarbons, and carbon monoxide. For each pollutant, the trends are reported in general terms for the nation and significant regional trends are noted. In Section 4.7, trends for other critical air pollutants not estimated by SEAS are discussed in a more qualitative manner. These include ozone, fine particulates, lead, and other toxic substances. The implications of all the emission trends are then discussed in Section 4.8. Some topics that have special relevance for air pollution are covered more fully in other chapters--in particular, Chapter 5, Global Atmospheric Pollution, and Chapter 11, Toxic Substances.

4.2 PARTICULATES

HIGHLIGHTS OF SECTION 4.2

- Between 1975 and 2000, total generation of particulates (before imposition of controls) is projected to double.
- If full compliance with existing air emission regulations were achieved, annual particulate emissions would decrease one-third between 1975 and 1985. SIP standards are scheduled to go into effect in 1982. Compliance with these standards should have a beneficial impact, especially in the near term. After 1985, emissions would increase gradually through 2000, to 85 percent of 1975 levels, due to economic growth and increasing fossil fuel combustion.

- Despite increases in total coal combustion by electric utilities and industrial boilers, particulate emissions from coal combustion are expected to decline if standards are met.

- The construction materials industry (which includes glass, cement, sand and gravel, and similar sources) is the major direct source of particulate emissions, accounting for approximately 40 percent of total net emissions.[7] This is the only industrial source for which particulate emissions in 2000 are projected to exceed 1975 levels.

- Assuming process changes in the steel industry, including conversion to basic oxygen and electric arc furnaces, particulate emissions from the steel industry are projected to decrease more sharply than emissions from other industries.

- The Middle Atlantic and Great Lakes Regions (Federal Regions III and V) are expected to show large reductions in emissions as a result of compliance with standards and slow economic growth. In contrast, although emissions in the South Central Region (Federal Region VI) are currently rather low, they are expected to increase substantially because of growth in aluminum production and widespread substitution of low-Btu coal for other fuels.

4.2.1 Introduction

Tiny particles of solid and liquid matter that can be suspended in air for brief or extended periods are defined as particulates. Such particles can be formed by natural processes as well as by human activities. Naturally occurring particulate generation has been estimated to account for as much as 90 percent of total suspended particulates (TSP) in the atmosphere.[8] However, generation from human activities such as industrial combustion and manufacturing is of greater environmental concern because such particulates often contain more toxic materials and they are more heavily concentrated in urban areas. The relationship between man-made direct emissions, man-made indirect or "fugitive" emissions, and natural particulate sources requires some clarification. Particulates emitted from crushing operations in the construction materials industry are examples of man-made direct emissions; particulates (or gases) escaping from inadvertent points of a building or an industry system are often termed fugitive emissions. In contrast, fugitive dust enters the air through the action of the wind either from a natural area or a human activity, e.g., a barren hillside or a plowed field. Fugitive dust is discussed in Section 4.8.

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[7] The reference source for particulate emissions data for the construction materials industry is U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Compilation of Air Pollutant Emission Factors, Third Edition, AP-42. These emission coefficients are for process steps such as crushers, pulverizers, kilns, dryers, coolers, etc. In general, fugitive dust such as blowing dust from sand piles or roads is not included.

[8] Stoker, H.S., and S.L. Seager, Environmental Chemistry: Air and Water Pollution, Second Edition, Scott, Foresman, and Co., Glenview, Illinois, 1976, p. 85.

Three caveats should be noted concerning SEAS projections of particulate emissions. First, SEAS estimates represent only particulates occurring directly from human activities; those from natural sources are generally not included. Thus for the Western and Northwest Regions (Federal Regions IX and X) where fugitive dust is the predominant source of total suspended particulates,[9] SEAS estimates represent only a small part of the particulates likely to be released in those areas. Second, SEAS estimates do not account for indoor sources of particulate emissions. However, they may be very important from a public health standpoint. Third, SEAS projections provide the total weight of particulate emissions; no distinctions are made regarding the size or composition of particulate matter. For this reason, separate discussions of fine particulates (those with diameters of less than 5 microns) and of particulates composed of lead and other trace elements are presented in Sections 4.7.2, 4.7.3, and 4.7.4.

Estimates of total particulate emissions from EPA's National Emission Data System for 1973 are about 10 percent higher than SEAS estimates for 1975. When the NEDS results are adjusted to factor out differences in the methods used to classify fuels into end-use categories, and in assumed levels of compliance with pollution control standards, NEDS and SEAS data are very similar. NEDS does not assume full compliance with standards; NEDS estimates assume sustained performance of installed control systems at design control efficiency and do not account for deterioration or recurring malfunctions. In addition, NEDS does not include the full impact of SIP requirements. Also, NEDS reports emissions from wood burning and other sources not included in SEAS. The lower emission levels reported by SEAS are a consequence of such differences.

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[9] Fugitive dust and its contribution to TSP are discussed in Section 4.8.2.

4.2.2 Emission Trends for Particulates

General Trends

Gross particulate generation (i.e., particulates present in untreated wastestreams) is expected to more than double between 1975 and 2000. Despite this large increase, if the emission controls required under the 1970 and 1977 Clean Air Act Amendments are implemented, net particulate emissions are projected to decrease by 15 percent over this time period under High Growth conditions, and by 25 percent under Low Growth conditions. This decline would be made possible by a combination of air pollution control devices and process changes, such as gravity settling chambers, cyclone collectors, and more effective baghouses and electrostatic precipitators.

Net emissions are projected to be lowest in 1982 (approximately 45 percent below 1975 levels under High Growth conditions), the year by which full compliance with SIP requirements is mandated. The environmental benefits of compliance with these standards should be maintained in the near term. After 1985, economic growth and increasing fossil fuel combustion are expected--in the absence of more stringent emission standards--to reverse the downward trend.

Major sources of net particulate emissions include the construction materials industry, electric utilities (principally coal-fired utilities), fuel combustion by industrial boilers, and steel production. The net emissions from each of these sources in 1975 are estimated in Table 4-3.

Despite large increases in total gross particulate generation between 1975 and 2000, total net emissions are projected to remain below 1975 levels. The trends in gross, captured, and net particulate emissions from each major source are illustrated in Figures 4-1 and 4-2 for the High Growth Scenario. In the following discussion, the factors that affect future emission levels from these sources are examined.

Major Industrial Sources

The construction materials industry[10] releases particulate matter into the air during process steps such as crushing,

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[10] The construction materials industry is comprised of the following manufacturing and mining industries, as classified according to the Standard Industrial Classification (SIC): glass (SIC 321, 322, and 323); cement (SIC 324); structural clay products (SIC 325); pottery products (SIC 326); concrete, gypsum, plaster, and lime (SIC 142); sand and gravel (SIC 144); clay ceramics and refractory minerals mining (SIC 145); and gypsum mining (SIC 1492).

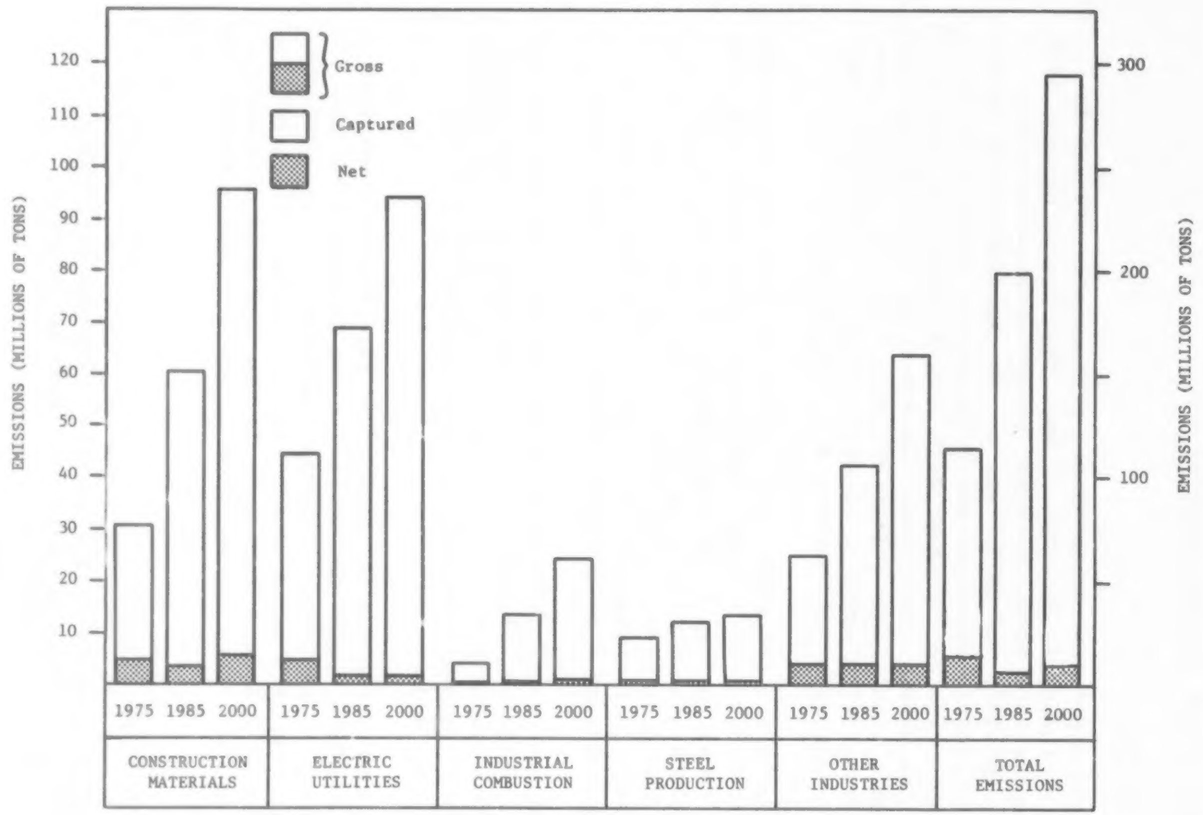

FIGURE 4-1
TRENDS IN GROSS, CAPTURED, AND NET PARTICULATE EMISSIONS, BY SOURCE
HIGH GROWTH SCENARIO
1975, 1985, 2000

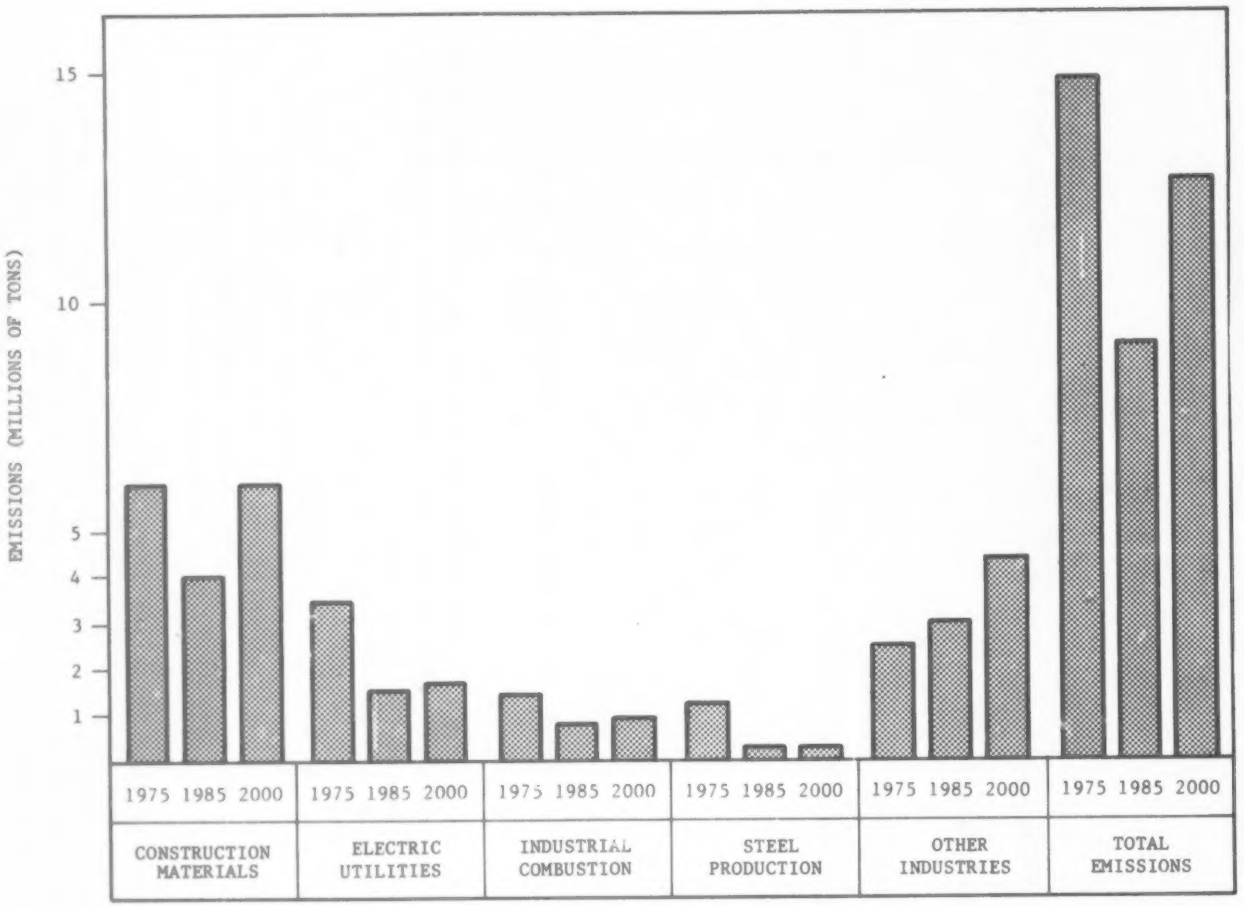

FIGURE 4-2
TRENDS IN NET PARTICULATE EMISSIONS, BY SOURCE
HIGH GROWTH SCENARIO
1975, 1985, 2000

TABLE 4-3
PRINCIPAL SOURCES OF NET PARTICULATE EMISSIONS
1975

Source	Net Emissions (10^6 Tons)	Percent of Total Net Emissions
Construction Materials Industry	6.0	41
Electric Utilities	3.5	24
Industrial Combustion	1.2	8
Steel	1.2	8
Other[a]	2.9	19
Total	14.8	100

[a] Sources each of which emits less than 6 percent of the total.

pulverizing and drying. These emissions are not as easily controlled as those from more enclosed operations. Nevertheless, net emissions in 1985 are expected to be at least 35 percent less than 1975 levels, in both the High and Low Growth Scenarios. This reduction would be achieved through the use of improved ventilation equipment and baghouses to comply with 1982 SIP requirements. However, as a result of increased levels of production between 1985 and 2000, assumed under High Growth conditions, net emissions in 2000 are projected to be about 5 percent higher than in 1975. Under Low Growth conditions, emissions by 2000 would still be 10 percent less than in 1975.

Net particulate emissions from steel production are projected to decrease by about 90 percent in both the High and Low Growth Scenarios between 1975 and 1985, despite a 30 percent increase in gross particulate generation. This decrease would result from assumed full compliance with SIP requirements by 1982, and to a lesser extent, from process changes that are assumed to occur within the industry, including conversion to the cleaner basic oxygen and electric arc furnaces.

Coal Combustion Sources

Electric utilities accounted for one-fourth of the nation's net particulate emissions in 1975, and coal-fired facilities produced 98 percent of the utility total. This is due to the fact that coal, unlike other fossil fuels, contains large quantities of mineral matter that, after combustion, remains behind as ash. Approximately 15 percent of this ash settles to the bottom of the combustor and is treated as a solid waste. The remaining 85 percent is sufficiently fine to be entrained by the combustion airstream and generated as fly ash.

In the High Growth Scenario, net particulate emissions from utilities are projected to decline about 65 percent between 1975 and 1985, despite a projected increase of over 80 percent in the generation of coal-fired electricity during that period (Figure 4-3). The decrease in emissions is expected if currently mandated control devices are installed both on coal-fired facilities on line before 1976 ("old" plants) and on those constructed since ("new" plants).

The SIP requirements that apply to old plants are less stringent than those that apply to new facilities because of the difficulties and expense of retrofitting.[11] As a result, old plants emit more particulates per unit of electricity generated than do new plants. In the High Growth Scenario for example, old coal-fired plants would generate 50 percent of the coal-fired electricity in 1985, yet they would produce about 70 percent of the particulates from all coal-fired plants. Under Low Growth conditions, in which a slower rate of power plant retirement is assumed, the proportion of particulates released by old plants would be even greater.

Electricity generation from coal-burning plants in 2000 is projected to be 40 to 50 percent higher than in 1985, based on the Low and High Growth Scenarios, respectively. Nevertheless, net particulate emissions are expected to be fairly constant from 1985 to 2000 because of the gradual retirement of old, "dirty" plants and their replacement by new facilities using Best Available Control Technologies (BACT).

As is true for electric utilities, the bulk of net particulate emissions from industrial boiler fuel use results from coal combustion (94 percent of the 1975 industrial combustion total). By 1985, after three years of compliance with 1982 SIP requirements, there would be a reduction of 60 to 70 percent (High Growth and Low Growth,

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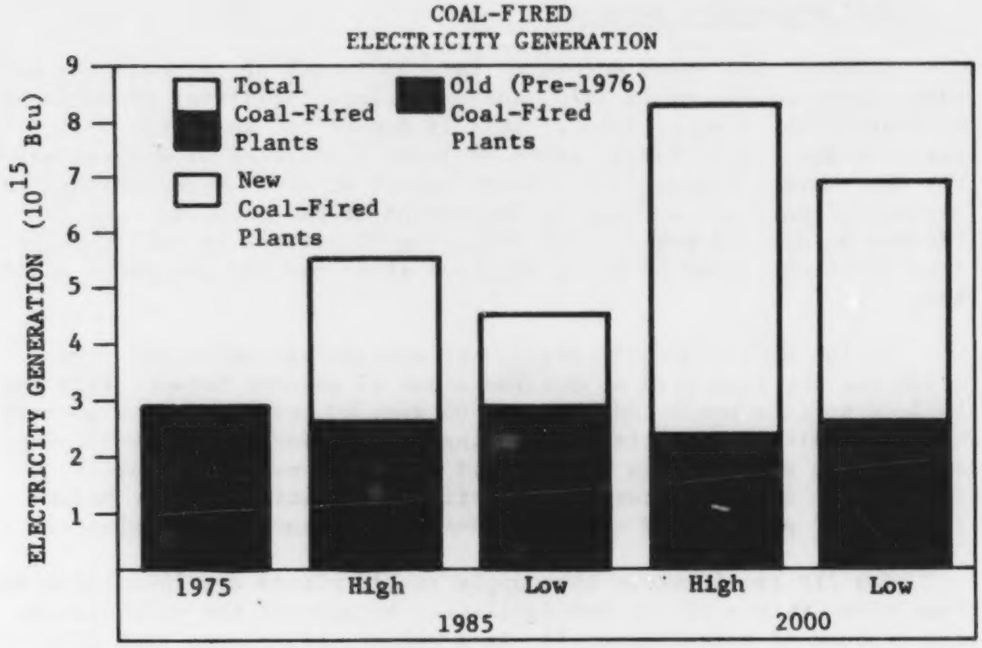
[11] The SIP standard for particulate emissions in New Mexico is an exception. It is more stringent than both NSPS and BACT standards.



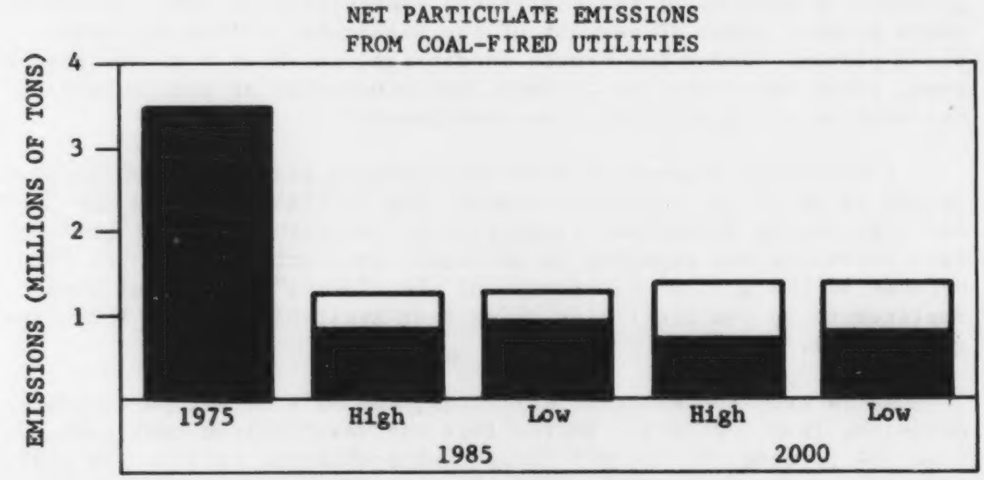


FIGURE 4-3
ELECTRICITY GENERATION AND NET PARTICULATE EMISSIONS FROM OLD (PRE-1976) AND NEW COAL-FIRED ELECTRIC UTILITIES 1975, 1985, 2000

respectively) in industrial coal combustion net emissions from 1975 levels. From 1985 to 2000, net emission levels from coal combustion are projected to remain fairly constant. In contrast, particulate emissions from industrial combustion of oil are projected to increase fourfold between 1975 and 2000 in both scenarios. However, since oil combustion generates far less particulate matter than coal combustion, it would remain a relatively small source of net particulate emissions in 2000.

Fuel combustion by electric utilities and industrial boilers combined accounted for one-third of the 15 million tons of particulates emitted in the nation in 1975. By 2000, net emissions from these sources are projected to decline 60 percent, even though total coal combustion is projected to increase 250 percent in the High Growth Scenario and 150 percent in the Low Growth Scenario between 1975 and 2000.

Analysis of Regional Trends

Regional variations in both gross and net particulate emissions are illustrated in Figure 4-4. Some regional trends differ substantially from the national trends because of differences in the composition of regional industrial sources, economic growth patterns, and state emissions requirements. Much greater reductions between 1975 and 2000 than the national average (15 percent) are projected for the Middle Atlantic and Great Lakes Regions (Federal Regions III and V), where net emissions would decline approximately 50 percent in the High Growth Scenario. In contrast, net emissions from the South Central Region (Federal Region VI) are projected to increase by almost 70 percent.

In 1975, particulate emissions in the Great Lakes Region (Federal Region V) accounted for 30 percent of the national total, more than any other region. By 2000, however, total net emissions from Federal Region V are projected to be less than half of the 1975 levels in both scenarios because of reduction in emissions from the coal-fired utilities located in the region. Nevertheless, Federal Region V is expected to remain one of the largest sources of national particulate emissions.

In 1975, the Southeast Region (Federal Region IV) accounted for about one-fourth of the nation's net particulate emissions. The two major sources of pollutant generation in this region are the construction materials industry and old (pre-1976) coal-fired utilities. In both the High and Low Growth Scenarios, net emissions from electric utilities in 2000 are expected to be 80 percent lower than in 1975 because of the retirement of pre-1976 utilities and the implementation of controls. During the same time period, net emissions

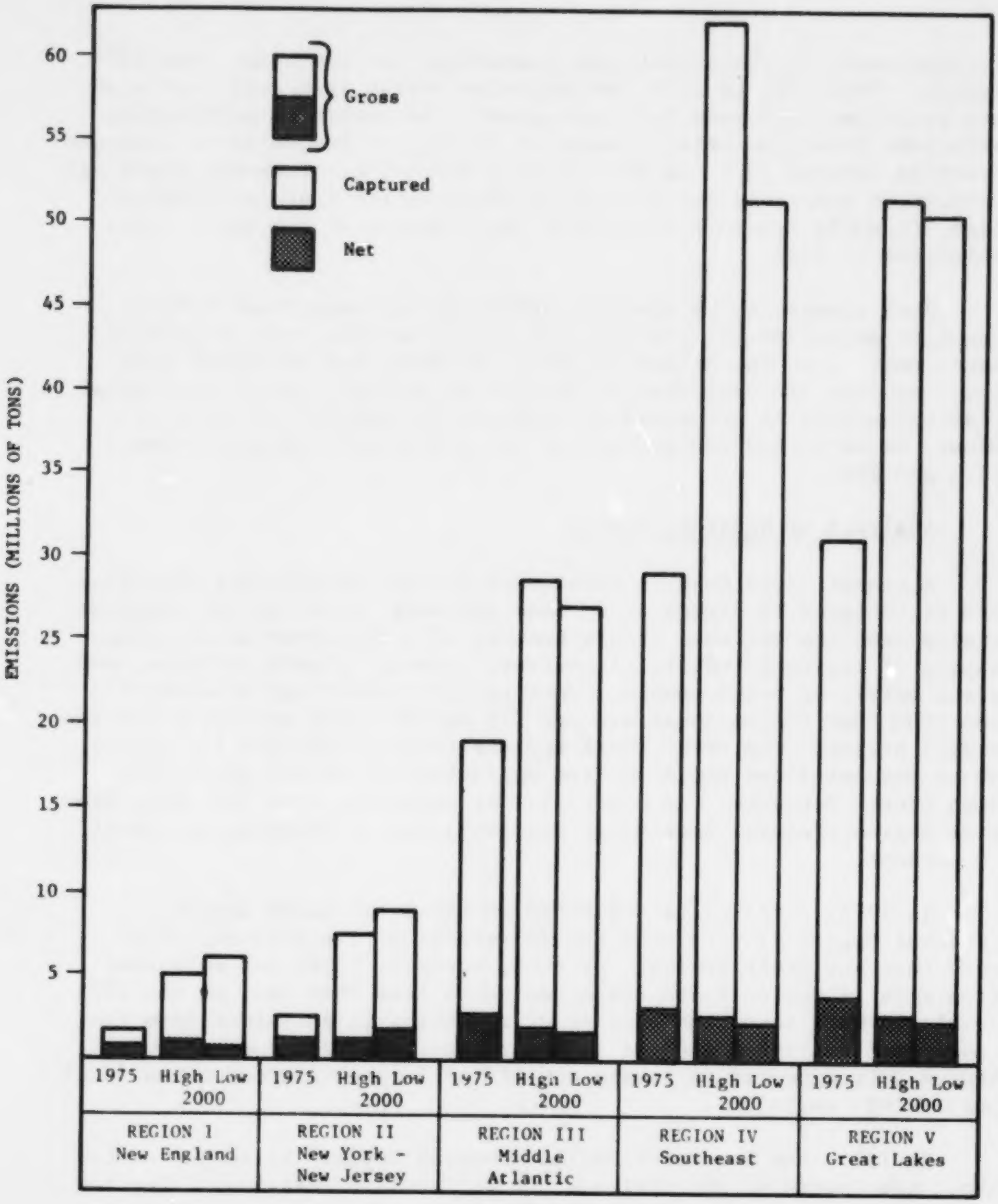


FIGURE 4-4
TRENDS IN REGIONAL PARTICULATE EMISSIONS
1975 AND 2000

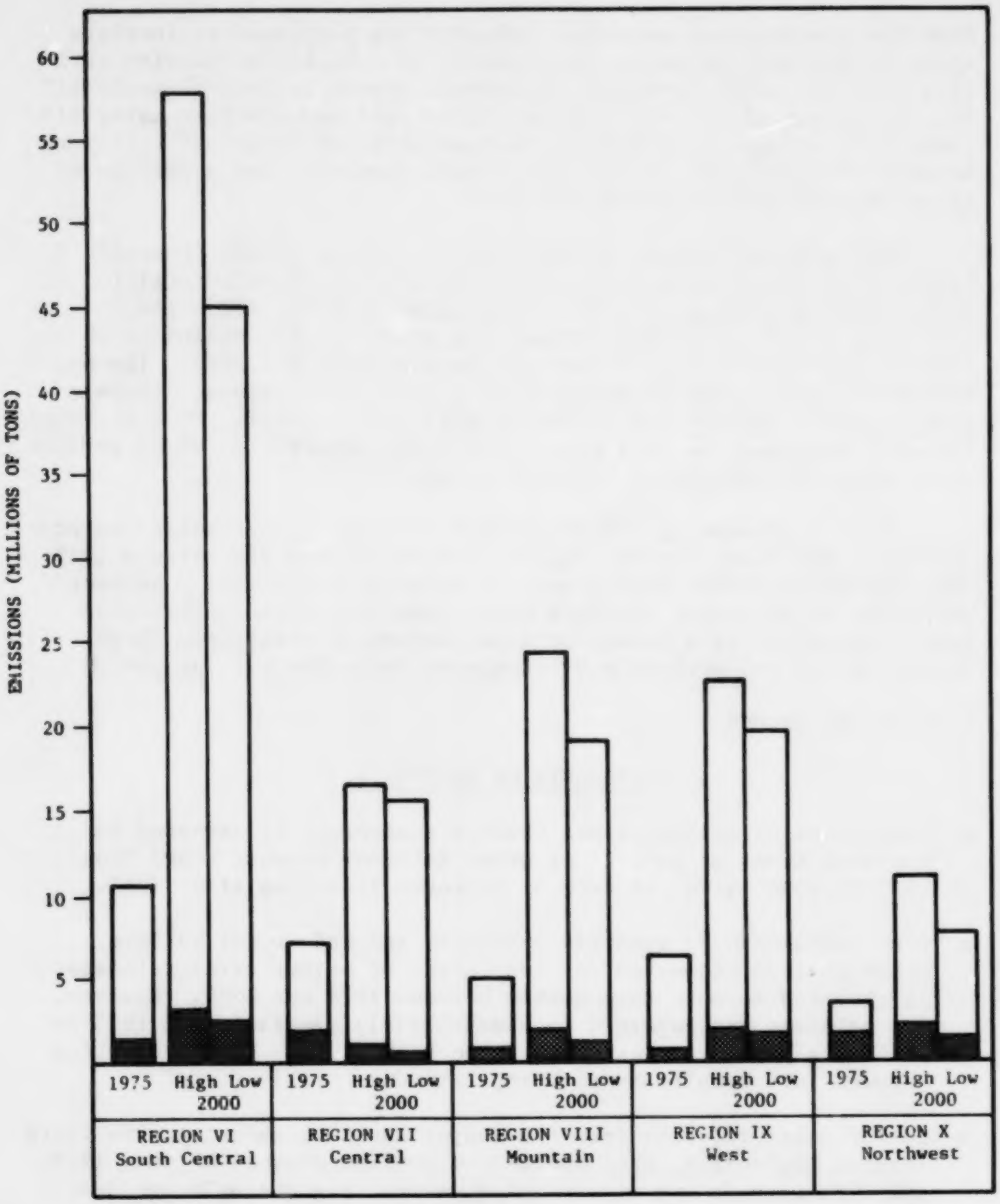


FIGURE 4-4
CONTINUED

from the construction materials industry are projected to increase about 50 percent, primarily as a result of a shift in building activity from the urban northeast to sunbelt states in Federal Region IV. The net effect of the electric utilities' and construction materials industry's changes is a fairly constant level of total net emissions between 1975 and 2000 in the High Growth Scenario, and a decline of 20 percent in the Low Growth Scenario.

Particulate releases in the Middle Atlantic Region (Federal Region III) constituted about one-fifth of the nation's total in 1975. With the assumption of full compliance with 1982 emission standards emissions in this region are projected to decline by 60 percent in the High Growth Scenario between 1975 and 1985. The magnitude of this reduction reflects projected slow regional economic growth as well as the imposition of pollution control. By 2000, particulate emissions in this region are still forecast to be 50 percent lower than 1975 levels in both scenarios.

About one-third of the 70 percent increase in net emissions projected in the South Central Region (Federal Region VI) between 1975 and 2000 would result from growth in aluminum production. Another one-fifth of the total increase would come from higher industrial coal combustion, as a result of substitution of relatively cheap Texas lignite and Western sub-bituminous coals for oil and gas.

4.3 SULFUR OXIDES

HIGHLIGHTS OF SECTION 4.3

- o Generation of sulfur oxides (before abatement) is expected to increase about as rapidly as Gross National Product (GNP) from 1975 to 2000, with the rate of increase lessening after 1985.

- o Coal combustion by electric utilities and industrial boilers, which in 1975 accounted for two-thirds of sulfur oxide releases, is expected to more than double between 1975 and 2000. However, SO_x releases are expected to remain fairly constant from 1975 to 2000 as a result of desulfurization techniques. This projection assumes full compliance with regulations.

- o Sulfur oxide releases from the copper smelting industry, the third largest SO_x source, are expected to decline sharply between 1975 and 1985 through use of control measures (e.g., single and double contact sulfuric acid plants and sulfite-bisulfite stack gas scrubbers). Between 1985 and 2000, emissions are expected to increase slightly because of higher copper output.

- Sulfur oxide releases in the South Central Region (Federal Region VI) are projected to triple between 1975 and 2000 under high growth economic conditions (and to double under low growth) because of rapid increase in use of coal by electric utilities and industrial combustors.

- The only regions in which sulfur oxide releases are projected to decline significantly between 1975 and 1985 are the Middle Atlantic, Great Lakes, and Western Regions (Federal Regions III, V, and IX). Between 1985 and 2000, this declining trend is expected to be arrested because of economic growth.

4.3.1 Introduction

The 1970 Clean Air Act required that ambient air quality standards and emission standards be developed for sulfur oxide (SO_x) emissions.

Nearly all of the direct emissions of sulfur dioxide (SO_2) into the atmosphere come from human activities. However, approximately one-half of the SO_2 in the atmosphere is generated indirectly as the result of the oxidation of hydrogen sulfide (H_2S). Atmospheric hydrogen sulfide issues from the decay of organic matter.[12]

Although not the most toxic form of sulfur oxide, sulfur dioxide is the easiest to control through stack gas treatment. The most hazardous of the sulfur oxides, sulfates (SO_4), are formed primarily by the oxidation of sulfur dioxide in the atmosphere, rather than being emitted directly by stationary sources. The regulatory strategy adopted has been to control only sulfur dioxide emissions. This has the indirect effect of controlling the formation of sulfates.

The presence of either sulfur dioxide or sulfates in the atmosphere may pose a threat to human health and can degrade the environment. Sulfur dioxide appears to exert direct effect on lung function; some sulfate compounds are suspected carcinogens.[13] Exposure can be exacerbated because these sulfur compounds are found in, or can be readily absorbed in, particulate matter which, when inhaled, may lodge in the lungs and cause respiratory irritations. Sulfates have refractive properties that scatter light, reducing visibility even at low concentrations. They can also increase the acidity of rainwater, producing acid rainfall that can have widespread adverse effects on aquatic systems.[14] Sulfur dioxide at high concentrations can severely damage crops and forest land.

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[12] Stoker, H.S. and S. Seager, Environmental Chemistry: Air and Water Pollution, Scott, Foresman and Company, Glenview, Illinois, 1976, pp. 65-66.

[13] National Academy of Sciences, Committee on Sulfur Oxides, Sulfur Oxides, Washington, D.C., 1978, pp. 8-27.

The SEAS model calculates the releases of all sulfur oxide compounds from stationary and mobile sources, excluding naturally occurring emissions. Currently, the system includes state-specific values for the sulfur content in fossil fuels, state-specific control requirements, and the sulfur removal efficiencies for various flue gas desulfurization (FGD) techniques. In addition, the rate with which old (pre-1976) electric power plants and industrial boilers are phased out is factored into the scenarios, as are the control requirements on new and old facilities.

The SEAS estimates of sulfur oxide residuals in 1975 were compared with information contained in the National Emissions Data System. The differences between SEAS and NEDS estimates of total SO_x were minimal.[15]

4.3.2 Emission Trends for Sulfur Oxides

General Trends

National gross generation of sulfur oxides between 1975 and 1985 is projected to increase at a faster rate than GNP. This rapid increase (about 4.4 percent per year in the High Growth Scenario) is expected to occur if coal is widely substituted as fuel in place of oil and gas. Gross sulfur oxide generation between 1985 and 2000 is projected to increase more slowly (about 2.5 percent per year in the High Growth Scenario). This rate, which is lower than the GNP growth rate, is due to a projected long-term decline in gross emissions per unit of manufacturing output. It reflects the anticipated impacts of both energy conservation and a continuing shift of consumer spending toward service industry goods that can be supplied with fewer pollutants than manufactured goods.

In spite of the large increases expected in gross generation levels over time, net sulfur oxide emissions are projected to remain relatively constant in both scenarios, given full compliance with pollution controls. Pollution abatement through the installation of control devices to comply with standards would result in a 10 percent decrease in projected net emissions in the High Growth Scenario and twice that decrease in the Low Growth Scenario by 1985. After 1985, continued economic growth would cause net emissions to increase gradually. By 2000, net emissions under High Growth conditions are expected to be about 6 percent higher than in 1975, while Low Growth projections are about 6 percent lower than 1975 levels.

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[14] Sawyer, J.W., "The Sulfur We Breathe," Environment, Vol. 20, March 1978, pp. 28-29.

[15] U.S. Environmental Protection Agency, 1973 National Emissions Report, National Emissions Data System of the Aerometric Emissions Reporting System, EPA-450/2-76-007, May 1976. (1975 NEDS data were not available at the time of this analysis.)

Since overall scenario differences are relatively small (about 10 percent) in all years, the following discussion of emissions from major sources presents results only from the High Growth Scenario except where significant differences occur.

Major Sources

The principal sources of net sulfur oxide emissions in 1975 are listed in Table 4-4. Electric utility emissions were by far the largest source. For both utilities and industrial combustion, 90 percent of the total emissions resulted from coal use.

TABLE 4-4
PRINCIPAL SOURCES OF NET SULFUR OXIDE EMISSIONS
1975

Source	Net Emissions (10^6 Tons)	Percent of Total Net Emissions
Electric Utilities	20.5	69
Industrial Combustion	2.4	8
Copper Smelting	2.3	8
Petroleum Refining	1.5	5
Residential/Commercial Fuel Use	1.4	5
Other	1.6	5
Total	29.7	100

Trends in sulfur oxide emissions from all major sources are illustrated in Figure 4-5. Electric utilities are projected to remain the single largest source of sulfur oxide through 2000. The use of control technologies--primarily limestone (calcium carbonate) scrubbers, which will probably be used to achieve SIP, NSPS, and revised NSPS (BACT) requirements--would result in a decrease of 20 percent in net utility emissions between 1975 and 1985. Between 1985 and 2000, net emissions from utilities are forecast to remain fairly constant, as the retirement of pre-1976 coal- and oil-fired plants counterbalances the emission increases from new coal-burning installations. Net emissions from industrial combustion activity, on the other hand, are expected to increase between 1975 and 2000, in spite of the use of emission control technologies because of a projected large increase in coal combustion in manufacturing.

Overall, although gross sulfur oxide emissions from coal combustion would increase rapidly between 1975 and 2000, net sulfur oxide emissions would be held to a small increase through use of stack gas desulfurization techniques. In 1975, total combustion of coal by all sources accounted for about 70 percent of the 30 million tons of net sulfur oxide emissions. Between 1975 and 2000, the use of coal for fueling combustion processes is projected to increase 250 percent in the High Growth Scenario, and net sulfur oxide emissions from coal combustion are projected to increase about 20 percent. In the Low Growth Scenario, coal utilization is projected to increase 150 percent, while net sulfur oxide emissions from coal combustion are projected to decrease about 20 percent. The installation of emission control measures is expected to be especially effective on large installations (e.g., industrial boilers burning over 250 million Btu of coal per hour, and electric utility power plants), which are to be strictly regulated by Federal New Source Performance Standards.

Net sulfur oxide emissions from copper smelting are projected to decline sharply between 1975 and 1985, about 70 percent in the High Growth Scenario. Reduced sulfur oxide emissions would be due primarily to control measures (e.g, single and double contact sulfuric acid plants and sulfite-bisulfite stack gas scrubbers incorporated into smelter plants) to meet emission regulations. Between 1985 and 2000, net emissions from smelters are expected to increase 10 percent, because of projected growth in the copper industry's output (about 15 percent).

Net emissions by petroleum refineries are projected to increase about 30 percent between 1975 and 2000, while gross emissions increase about 40 percent. The High Growth Scenario assumes that the nation will move aggressively to decrease its dependence on imported crude oil and petroleum products by conserving and/or substituting other fuels wherever possible. It is also assumed that the sulfur

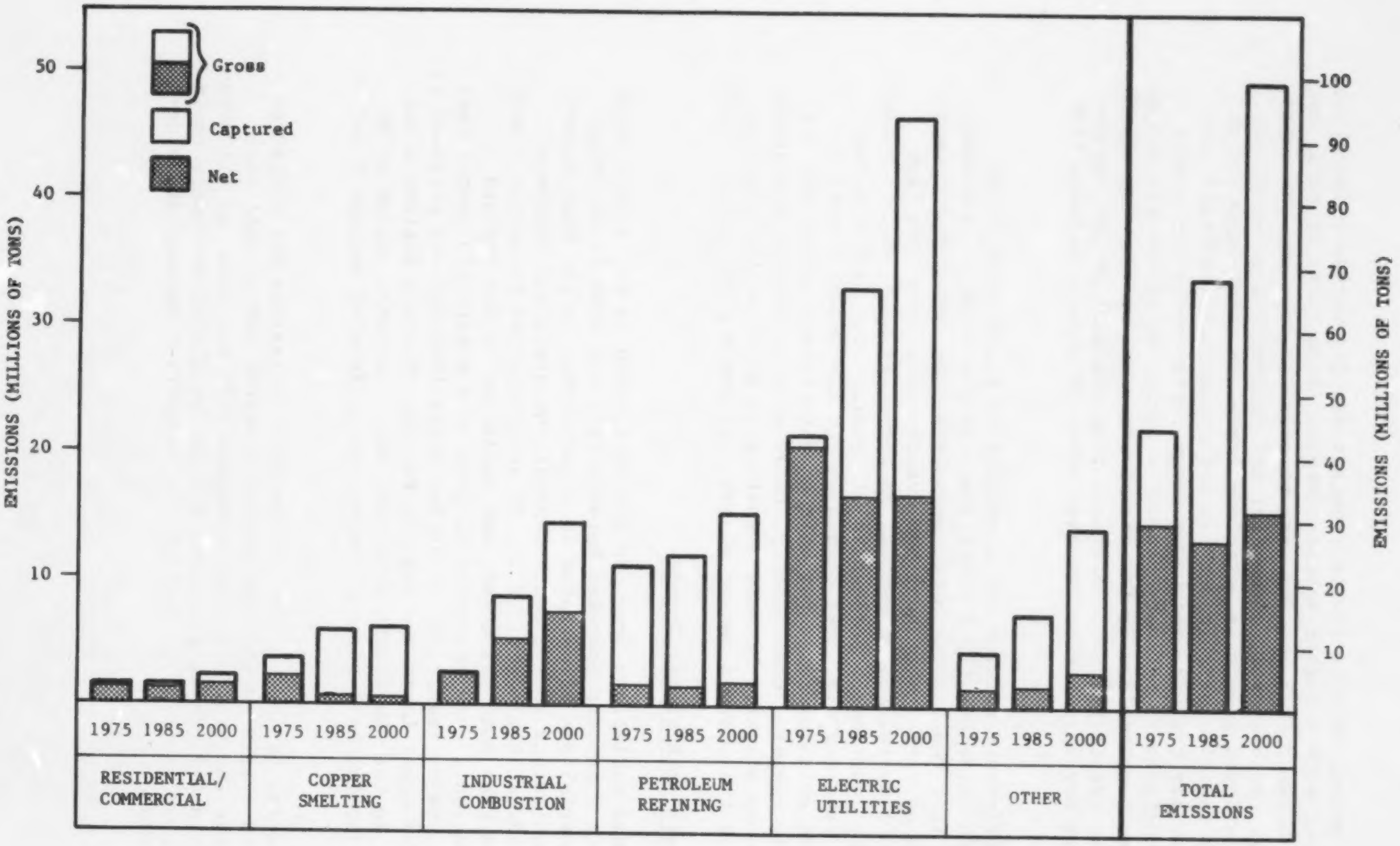

FIGURE 4-5
TRENDS IN SULFUR OXIDE EMISSIONS, BY SOURCE
HIGH GROWTH SCENARIO
1975, 1985, 2000

content of petroleum will remain constant despite economic incentives to refine oil with a higher sulfur content. Reductions in total petroleum use between 1975 and 2000 are recorded in some end use categories (e.g., auto travel, commercial and residential consumption). However, continued growth in petroleum demand in other segments of the economy (particularly industrial and commercial feedstock uses, trucking and air travel) overshadow these improvements and result in required additions to refinery capacity. Gross emissions are assumed to be somewhat controlled by the use of Claus sulfur recovery plants and tail gas treatment. Net emissions from residential and commercial sources are expected to increase about 20 percent between 1975 and 2000.

The difference between the scenarios in projections of net sulfur oxide emissions (10 percent lower in Low Growth) is primarily due to the fact that sulfur oxide emissions from industrial combustion are 35 percent lower under Low Growth conditions than High Growth. Utility-related emissions, on the other hand, differ between scenarios by less than 5 percent in all years. Due to the slower retirement rate for old power plants in the Low Growth Scenario, sulfur oxide emission rates per unit of electricity output are correspondingly higher. Consequently, total utility emissions continue to differ only slightly between scenarios in spite of the widening disparity in the assumed amount of new coal power plant construction.

Analysis of Regional Trends

Regional variations from the national trend in net sulfur oxide emissions (a 5 percent increase between 1975 and 2000 in the High Growth Scenario) are illustrated in Figure 4-6. In the High Growth Scenario, emissions in the South Central, Mountain and Northwest Regions (Federal Regions VI, VIII, X) are projected to increase much faster than this national trend, and emissions in New England (Federal Region I) are projected to grow at a moderately faster rate. Conversely, major reductions in sulfur oxide loadings are presumed to occur in the Great Lakes and Western Regions (Federal Regions V and IX). Even in the Low Growth Scenario, where national sulfur oxide emissions decline by 5 percent, emissions in Federal Regions I and VI increase.

In Federal Region VI, net sulfur oxide emissions are projected to more than triple in the High Growth Scenario and to more than double in the Low Growth Scenario between 1975 and 2000, as illustrated in Figure 4-7. These increases are the result of extremely rapid growth in coal and oil use in both new industrial boilers and electric utilities.

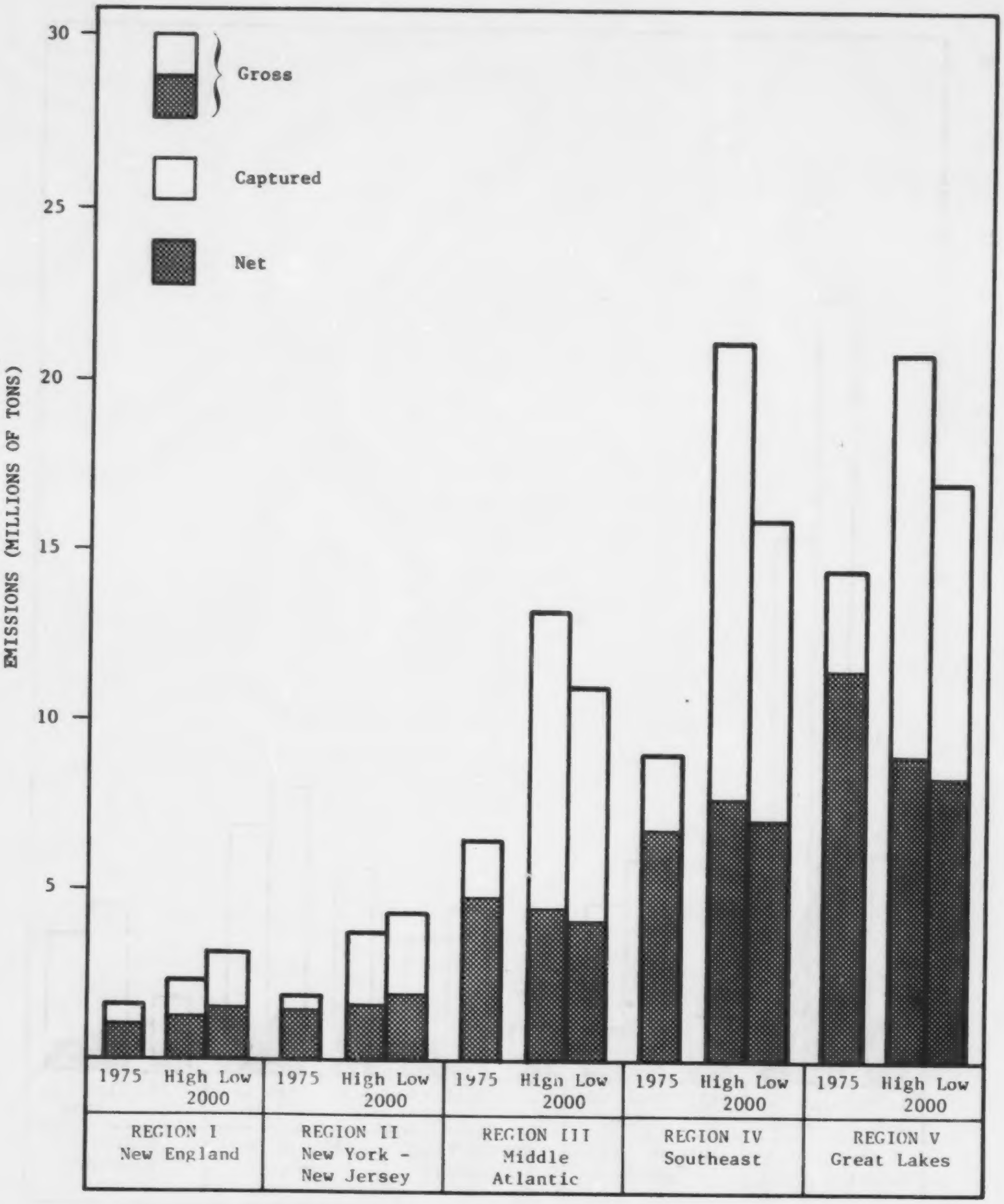

FIGURE 4-6
TRENDS IN REGIONAL SULFUR OXIDE EMISSIONS
1975 AND 2000

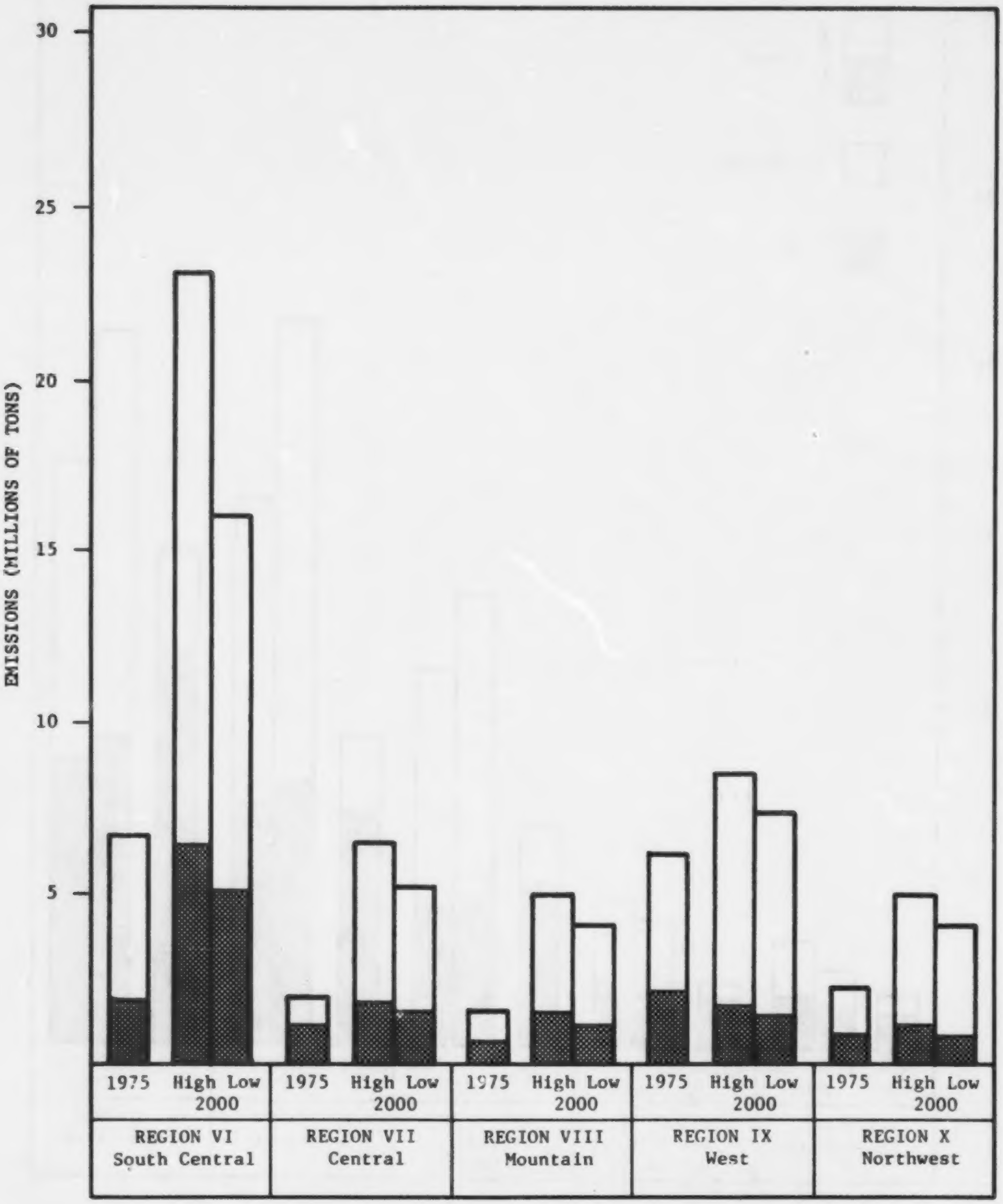

FIGURE 4-6
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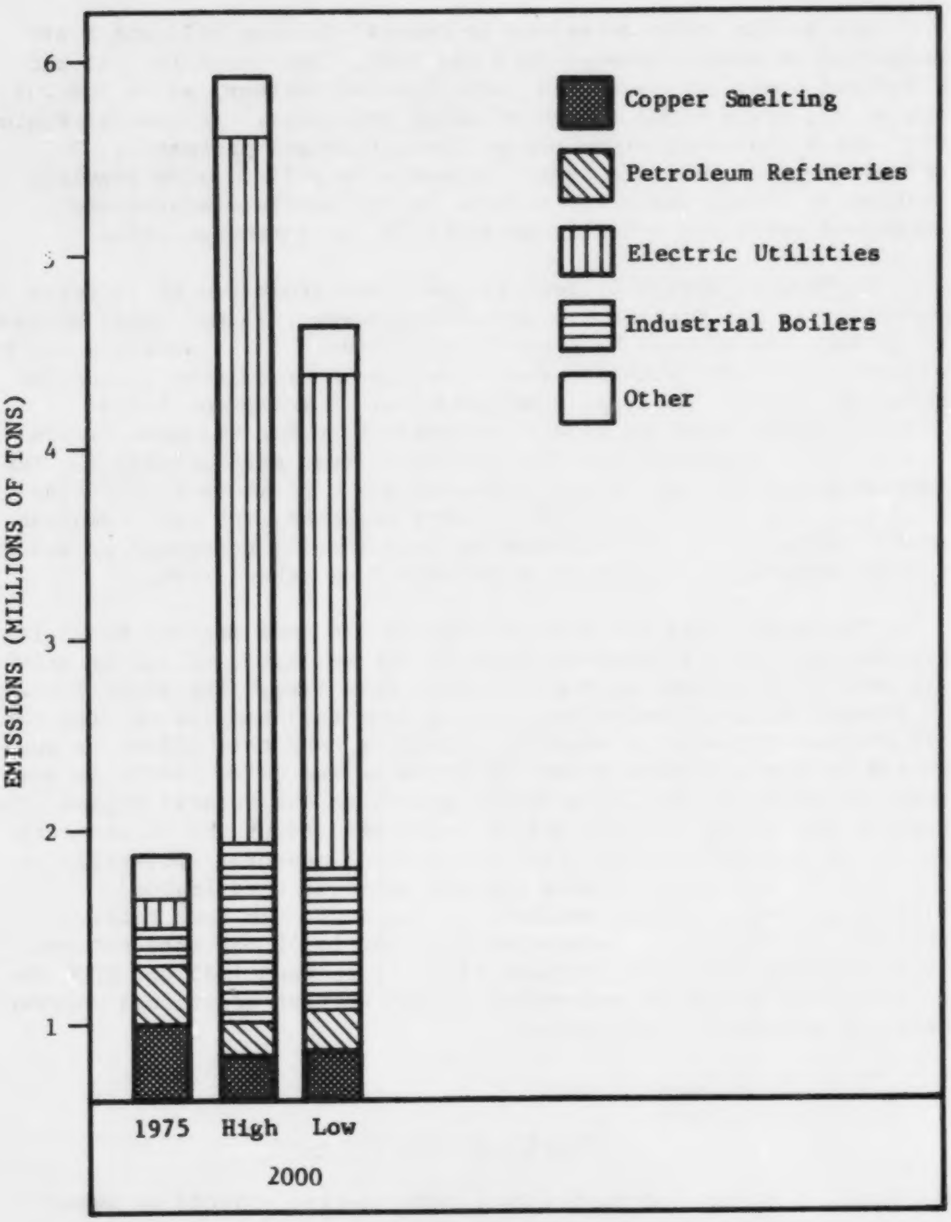

FIGURE 4-7
TRENDS IN NET SULFUR OXIDE EMISSIONS
REGION VI
1975 AND 2000

Net sulfur oxide emissions in Federal Regions VIII and X are projected to double between 1975 and 2000. Increases in coal and oil-fired power generation in these Federal Regions, as in Federal Region VI, are a major source of added emissions. In Federal Regions VIII and X, however, other energy production and processing activities also generate large increases in sulfur oxide loadings--initiation of oil shale development in the mountain states and increased petroleum refining activity in the northwest area.

In Federal Region I, net emissions are projected to increase by one-fifth in the High Growth Scenario between 1975 and 2000, because of greater use of coal by electric utilities. This is partly due to assumed compliance with the fuel substitution requirements enacted under the Energy Supply and Environmental Coordination Act of 1974.[16] These existing plants are subject to SIP emission limitations, which generally are less stringent than NSPS standards. The increased use of coal in the northeast may contribute to existing acid rain and sulfur oxide (SO_2) non-attainment problems. Ambient sulfur oxide levels are affected by both locally generated emissions and atmospheric transport of pollutants from other areas.

The Great Lakes and Western Regions (Federal Regions V and IX) are the only Federal Regions in which net emissions of sulfur oxides are projected to decline significantly over time. The major decline in Federal Region V emissions results from full compliance with the SIP standards placed on electric utilities, and this effect is supplemented by the fact that growth in gross sulfur oxide levels is somewhat inhibited by lagging economic growth in the Federal Region. In Federal Region IX, overall sulfur oxide reductions can be directly traced to the addition of effective control measures (primarily in the form of single and double contact sulfuric acid [H_2SO_4] plates) placed on copper smelters in the area. In both Federal Regions, emissions are reduced sharply (40 to 50 percent) between 1975 and 1985, and then increase slightly between 1985 and 2000 due to continued growth in industrial output without additional improvements in abatement efficiencies.

4.4 NITROGEN OXIDES

HIGHLIGHTS OF SECTION 4.4

o Nitrogen oxides can have significant adverse effects on human health and the environment. In addition to direct respiratory effects, atmospheric NO_x is an important contributor to photochemical smog and acid precipitation.

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[16] Public Law 93-319, 88 Stat. 246, 15 U.S.C. 791 et seq.

- Electric power generation and motor vehicle transportation are expected to account for about one-third each of NO_x generation from 1975 to 2000.

- Growth in fuel use for industrial combustion is projected to increase net NO_x emissions from that source threefold under high economic growth conditions between 1975 and 2000.

- Because of transportation emission controls, net emissions from mobile sources are projected to decline between 1975 and 2000, even though transportation activity increases.

- Emissions in the Southeast, South Central, Mountain, and Northwest Regions (Federal Regions IV, VI, VIII, and X) are projected to increase more rapidly than the national average. Emission levels in the New England and New York-New Jersey Regions (Federal Regions I and II) are expected to increase more slowly than the national average.

4.4.1 Introduction

The nitrogen oxides (NO_x) of interest here are compounds of nitrogen and oxygen that are formed during the combustion of fossil fuels. Although ambient air quality standards for nitrogen dioxide (NO_2) were established as part of the 1970 Clean Air Act Amendments few sources of nitrogen oxide emissions are currently required to adopt controls. Increasing concern over the health effects of nitrogen dioxide and possible interaction of nitrogen oxides with other atmospheric pollutants has stimulated the evaluation of the need for a short-term (3-hour) standard that would require stricter emission controls during periods in which emissions are greatest (i.e., "rush hours"). New standards that may be more stringent than those presently in force are therefore being considered.

Nitrogen oxides are believed to have significant negative effects on health and the environment, either directly or through nitrogen oxide (particularly nitrogen dioxide) participation in photochemical reactions. Direct effects of nitrogen oxide emissions include lowered resistance to respiratory infections, impaired pulmonary function, and damage to materials and vegetation.[17] Indirect, but often more significant effects result from the interaction of nitrogen oxides with other pollutants to form photochemical oxidants.[18] Other adverse effects include formation of acid rain, which results after nitrogen dioxide reacts with water in the air to form nitric acid (HNO_3), and atmospheric nitrates. The presence of nitrate aerosols and salts in the atmosphere is suspected of contributing to respiratory disorders, elevated levels of methemoglobin (particularly in children), contamination of land and water through precipitation containing nitrates, and formation of photochemical smog. However, the data available on health and environmental effects of nitrates are inconclusive.[19]

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[17] National Academy of Sciences, Nitrogen Oxides, Washington, D.C., 1977, pp. 159.

[18] The effects of photochemical oxidants are discussed in Sections 4.7.1 and 4.8.6.

Current technology for controlling nitrogen oxide emissions is largely limited to combustion modifications. Experimentation with nitrogen oxide scrubbers is currently under way in both this country and Japan.[20]

The SEAS data base is well suited to the projection of nitrogen oxide emissions. Energy production and consumption activities, the primary sources of nitrogen oxides are treated in great detail within the model. Projections of emissions reflect distinctions among alternative energy production processes and among applicable environmental regulations. The model estimates nitrogen oxide emissions from five transportation modes: automobile, bus, truck, air, and rail.

Comparisons of SEAS nitrogen oxides estimates for 1975 with nitrogen oxides data for 1973 from EPA's National Emissions Data System indicate close correspondence. These estimates were found to differ by less than 10 percent.[21]

4.4.2 Emission Trends for Nitrogen Oxides

For 1975, gross and net emissions of nitrogen oxides were essentially the same, since there were no control requirements for most sources. Of the four major sources of net nitrogen oxides releases

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[19] National Academy of Sciences, Nitrates: An Environmental Assessment, Washington, D.C., 1978, Chapter 1.

[20] U.S. Environmental Protection Agency, 1973 National Emissions Report, National Emission Data System for the Aerometric Emissions Reporting System, EPA-450/2-76-007, May 1976.

[21] U.S. Environmental Protection Agency, Technical Assessment of NO_x Removal Processes for Utility Application, Interagency Energy-Environment Research and Development Program Report, EPA-600/7-77-127, November 1977, p. xiv.

(Table 4-5), electric power generation and motor vehicle travel were by far the most significant. Almost two-thirds of utility-related emissions were from coal-fired power plants. Emissions from transportation activity were about equally divided between automobiles and trucks.

Gross emissions of nitrogen oxides are projected to increase over time in all 10 Federal Regions at a rate somewhat faster than the rate of growth assumed for total energy consumption because of expected increases in coal use by industry and electric utilities. Although oxides of nitrogen are primarily formed during combustion processes by the interaction of nitrogen in the air with oxygen in the presence of heat, the levels of nitrogen oxides formed are somewhat dependent on the temperature at which combustion occurs and the nitrogen content of the fuel being burned. Due to these latter

TABLE 4-5
PRINCIPAL SOURCES OF NET NITROGEN OXIDE EMISSIONS
1975

	Net Emissions (10^6 Tons)	Percent of Total Net Emissions
Electric Utilities	6.3	34
Transportation	6.2	33
Industrial Combustion	2.0	11
Petroleum Refining	1.5	8
Other[a]	2.6	14
Total	18.6	100

[a] Sources each of which emits less than 6 percent of the total.

factors, both utility and industrial coal-fired boilers are estimated to generate significantly higher levels of nitrogen oxides per Btu combusted than oil-fired units (about 30 percent). Both fuels, in turn, generate somewhat higher levels of nitrogen oxides than gas combustors.

By 2000, gross emissions in the High Growth Scenario are projected to be 90 percent higher nationally than in 1975; in the Low Growth case, the projected increase is 55 percent. The difference between scenarios in nitrogen oxides discharges is less than 15 percent in 1985 and about 20 percent in 2000. These differences are almost equal to the projected differences in energy use between the two scenarios. Utilities and transportation would remain the principal emission sources in all years for both scenarios, although nitrogen oxides releases from industrial combustion are projected to become more significant over time.

Trends in net nitrogen oxide emissions from major sources under the High Growth Scenario are illustrated in Figure 4-8. By 2000, the relative importance of these sources changes sharply; the extensive use of coal and oil in place of natural gas as an industrial boiler fuel results in a threefold increase in combustion-related pollutants from 1975 to 2000.

Although transportation activity is projected to increase, net emissions from mobile sources would decline in both scenarios because of the assumed implementation of transportation emission controls. The diverging relationship between elements affecting transportation emission projections is shown in Table 4-6.

Total nitrogen oxide emissions projected under the Low Growth Scenario are about 10 percent lower than those under High Growth conditions. Estimates from the two scenarios for 2000 are contrasted in Table 4-7. It is somewhat surprising that the two cases do not diverge more sharply over time. Much of this effect is due to trends in electric utility industries, as projected nitrogen oxide emissions from this source differ between scenarios by only 2.4 percent in 2000. In the Low Growth Scenario, nitrogen oxide emissions from old (pre-1976) utilities would remain uncontrolled under current environmental standards, while control requirements for new sources would result in moderate emission reductions through modifications such as staged combustion. Therefore, the slower rates of power plant retirement assumed in the Low Growth Scenario result in higher levels of nitrogen oxide emissions per unit of electricity production.

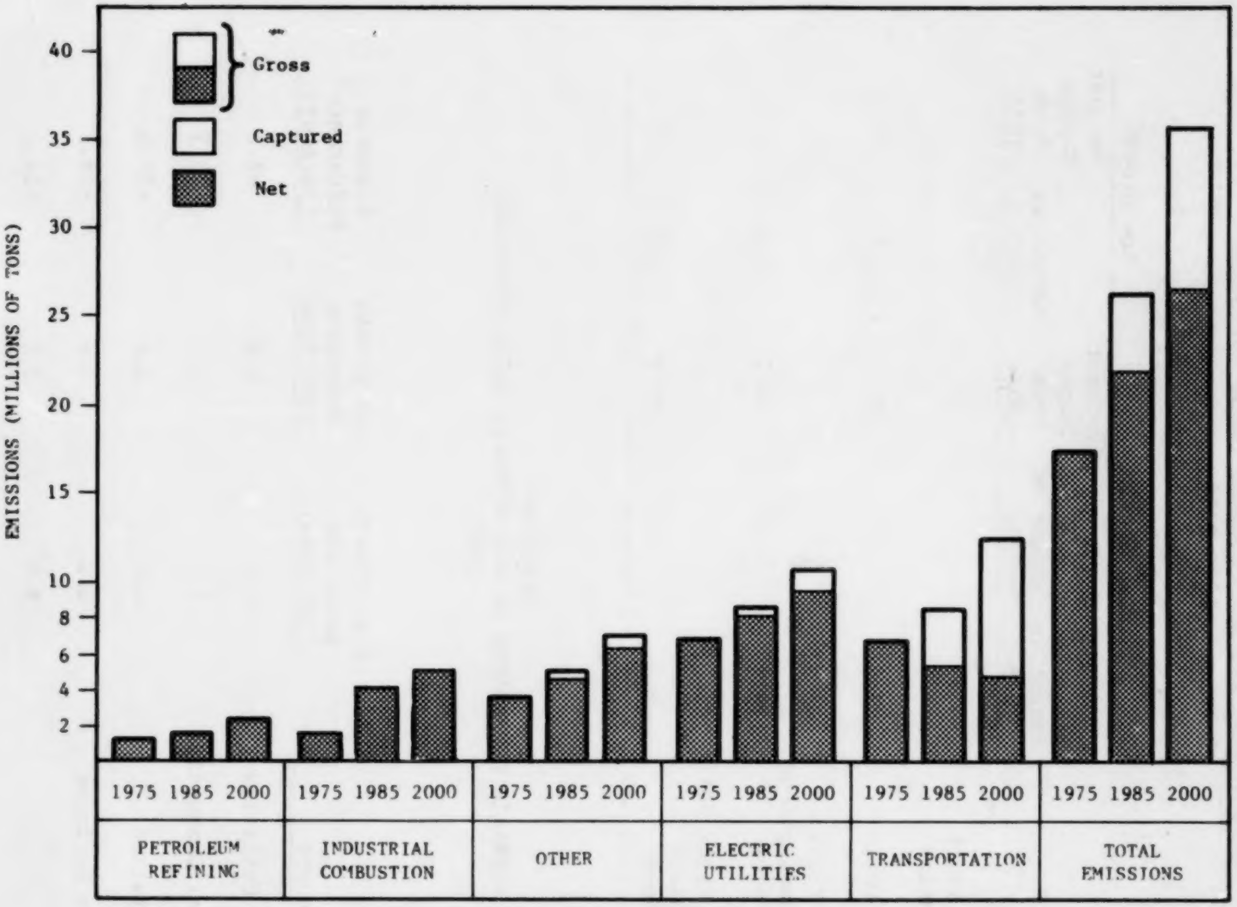


FIGURE 4-8
TRENDS IN NITROGEN OXIDE EMISSIONS, BY SOURCE
HIGH GROWTH SCENARIO
1975, 1985, 2000

TABLE 4-6
TRENDS IN MOTOR VEHICLE TRANSPORTATION ACTIVITY, ENERGY USE, AND NET NITROGEN OXIDE EMISSIONS 1975-2000

	High Growth			Low Growth	
	Amount in 1975	Amount in 2000	Percent Change From 1975	Amount in 2000	Percent Change From 1975
Auto and Truck Vehicle Miles Traveled (10^{12} VMT)	2.3	5.1	121.7	3.2	39.1
Auto and Truck Energy Consumption (10^{15} BTU)	14.1	14.1	-0.1	8.3	-14.1
Auto and Truck Net NO_x Emissions (10^6 Tons)	6.2	4.6	-25.8	2.9	-53.2

TABLE 4-7
SCENARIO COMPARISON OF NET NITROGEN OXIDE EMISSIONS 2000

Source	High Growth Emissions (10^6 Tons)	Low Growth Emissions (10^6 Tons)	Scenario Difference[a] (Percent)
Electric Utilities	9.2	9.0	-2.2
Industrial Combustion	5.5	4.1	-25.5
Transportation	4.6	2.9	-37.0
Petroleum Refining	2.2	1.8	-18.2
Other	5.0	5.7	+14.0
Total	26.5	23.5	-11.3

[a] Scenario Difference = $\frac{\text{(Low Growth - High Growth)}}{\text{High Growth}}$

Regionally, both High and Low Growth Scenarios assume a continued movement of population and industrial activity from northeastern urban areas to the sunbelt portions of the country. In addition, certain areas of the country (such as Texas and the Rocky Mountain states) are expected to greatly expand their use of coal as a combustion fuel. Consequently, gross and net nitrogen oxide emissions in Federal Regions IV, VI, VIII, and X grow much more rapidly than the national average. In New England and New York-New Jersey (Federal Regions I and II), coal currently represents a very small fraction of total fuel use and thus even though coal use is projected to increase dramatically, slow economic growth should result in slow growth in total energy consumption, and hence nitrogen oxide emissions which grow at a lower rate than the national average. These regional trends are illustrated in Figure 4-9.

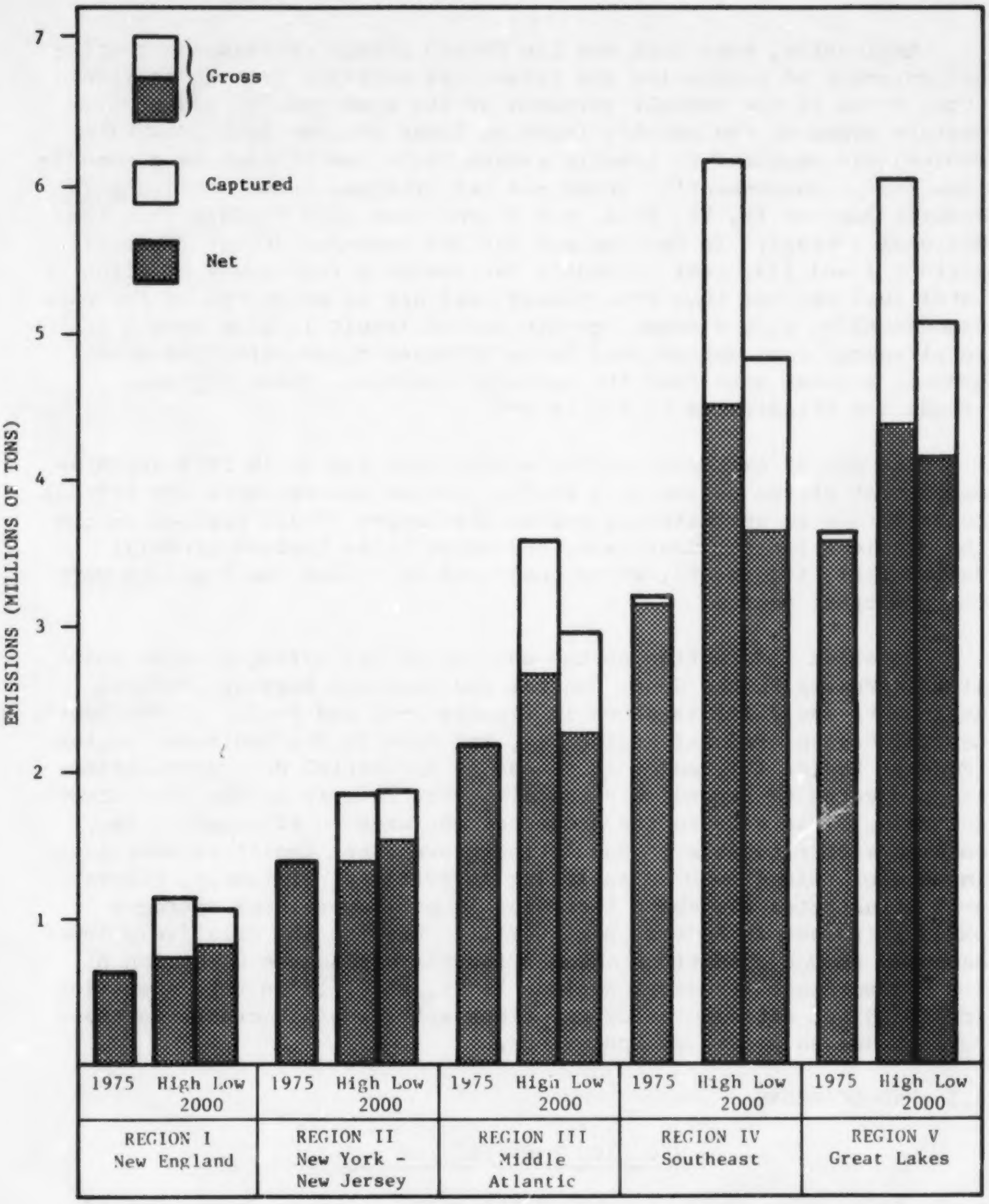
The mix of emission sources within each region in 1975 approximated that of the nation as a whole. Mobile sources were the largest contributors to net nitrogen oxides discharges in all regions except the Middle Atlantic, Southeast, and Great Lakes Regions (Federal Regions III, IV, and V), where coal- and oil-fired power plants were the principal source.

Detailed information on the sources of net nitrogen oxide emission increases in the South Central and Mountain Regions (Federal Regions VI and VIII) is shown in Figures 4-10 and 4-11. In the South Central Region (Federal Region VI), and also in the Southeast Region (Federal Region IV), major increases in industrial coal applications are projected to expand very rapidly, particularly in the High Growth Scenario. This adds to the projected increase in nitrogen oxide emissions attributable to population growth, and amplifies subsequent impacts of this growth on polluting activities. Similarly, Figure 4-11 illustrates the sharp increases in utility-related nitrogen oxide emissions in Federal Region VIII. Despite the relatively lower economic growth conditions assumed for the northeastern portion of the United States (Federal Regions I, II, and III) in both scenarios, gross and net nitrogen oxide emissions still would increase in these regions due to growth in energy use.

4.5 HYDROCARBONS

HIGHLIGHTS OF SECTION 4.5

- In 1975, over three-fourths of the urban counties in the United States failed to comply with primary ambient air standards for photochemical oxidants. Hydrocarbon emissions, which contribute to the formation of oxidants, rank as a significant air quality problem.



NOTE: In 1975, net and gross emissions are virtually identical since controls had not yet been applied.

FIGURE 4-9
TRENDS IN REGIONAL NITROGEN OXIDE EMISSIONS
1975 AND 2000

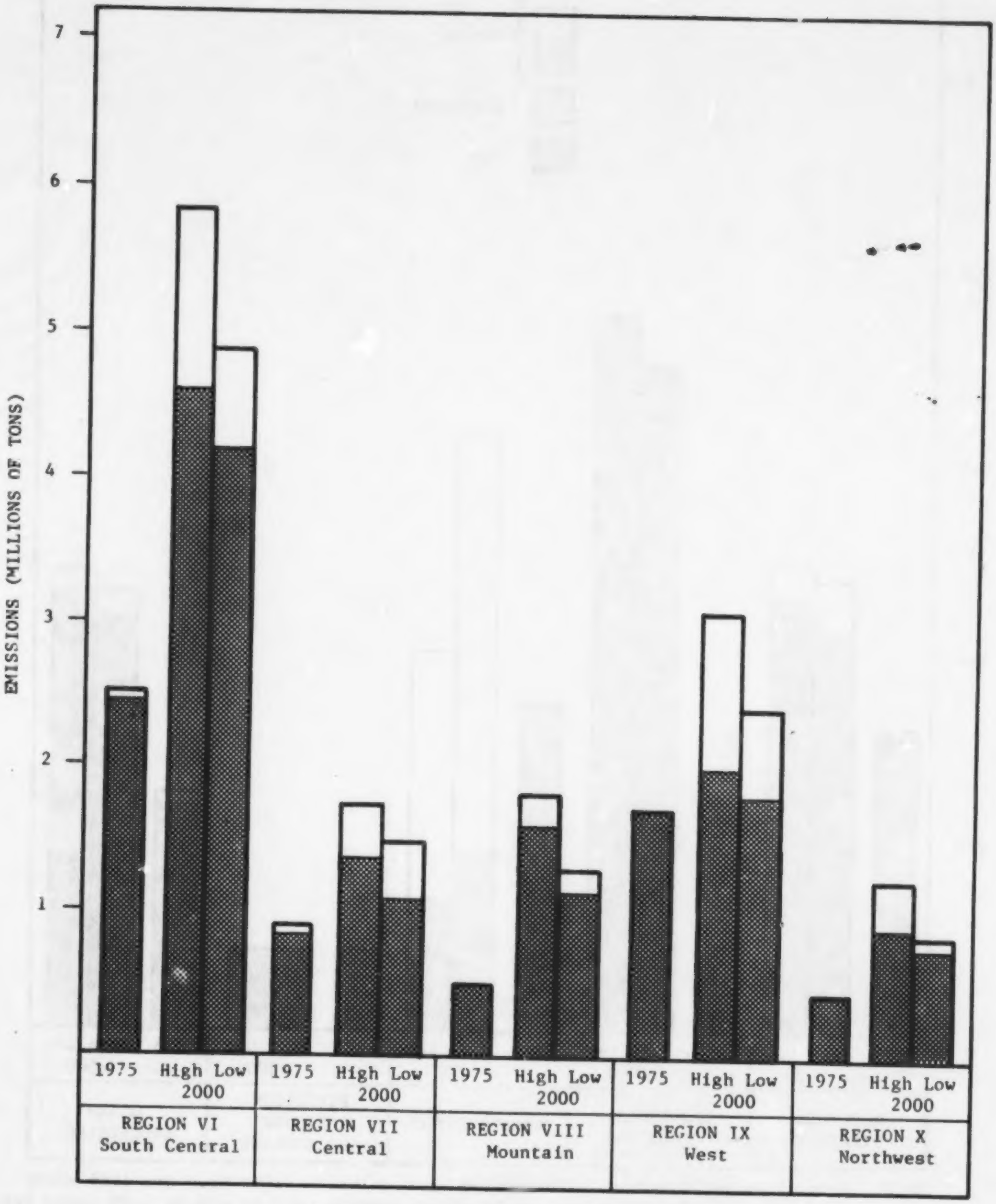


FIGURE 4-9
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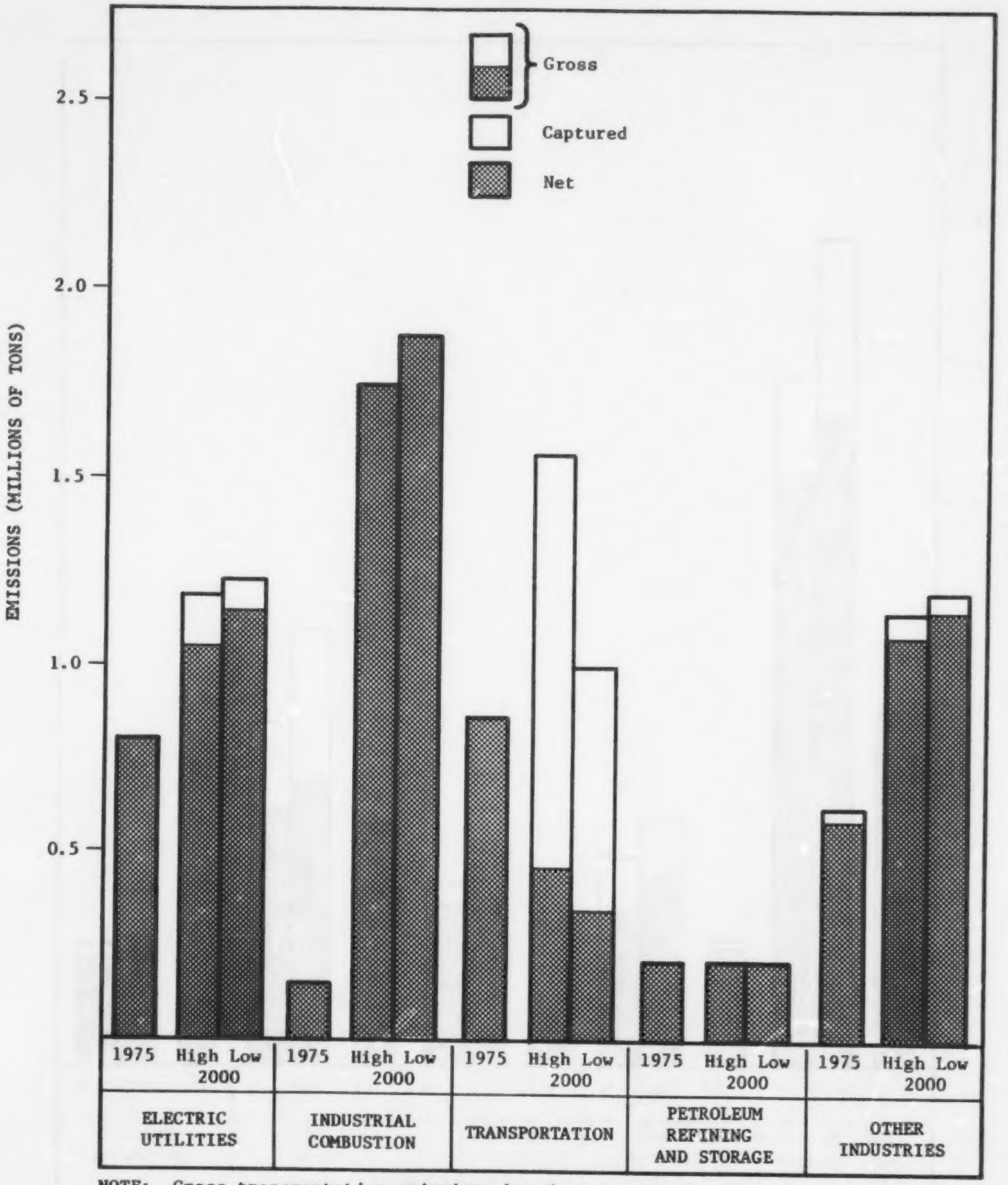
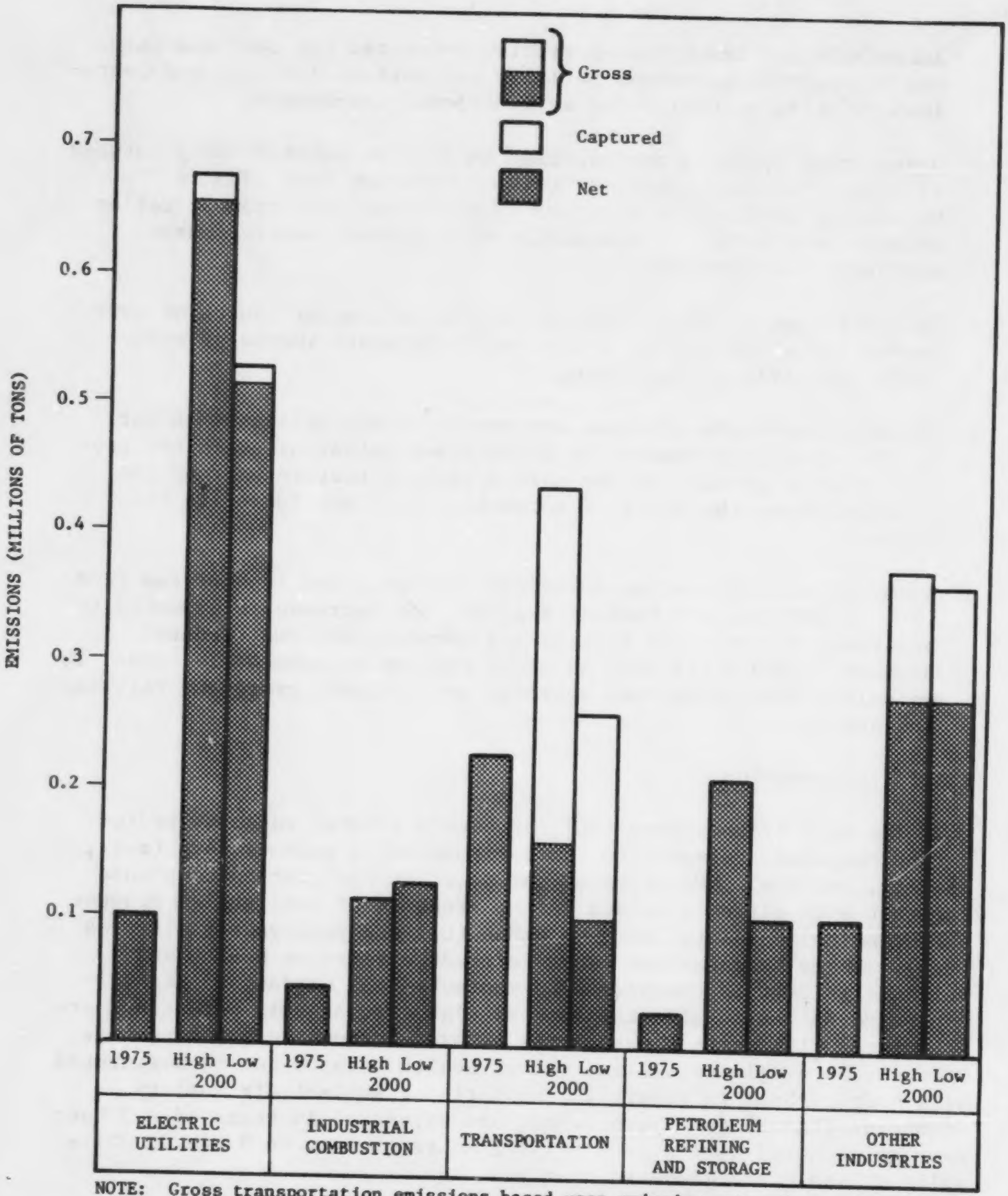


NOTE: Gross transportation emissions based upon emission rates from pre-1968 motor vehicles. Engine deterioration based on average vehicle age of 5.99 years for autos, and 7.15 years for trucks. Engine deterioration emission factor based upon pre-1968 vehicles.

FIGURE 4-10
NITROGEN OXIDE EMISSIONS, BY SOURCE
REGION VI
1975 AND 2000



NOTE: Gross transportation emissions based upon emission rates from pre-1968 motor vehicles. Engine deterioration based on average vehicle age of 5.99 years for autos, and 7.15 years for trucks. Engine deterioration emission factor based upon pre-1968 vehicles.

FIGURE 4-11
NITROGEN OXIDE EMISSIONS, BY SOURCE
REGION VIII
1975 AND 2000

- Automobile and truck transportation accounted for over one-half the hydrocarbon emissions in 1975, and surface coatings and petroleum refining accounted for an additional one-fourth.

- Hydrocarbon releases are expected to decline substantially between 1975 and 1985, and remain relatively constant from 1985 to 2000, because of projected reductions in emissions from transportation sources as a result of compliance with present mobile source abatement requirements.

- The petroleum refining industry is the only major source of hydrocarbon emissions that is projected to generate increased pollutants from 1975 through 2000.

- Emission standards are more stringent for automobiles than for trucks; thus improvements in hydrocarbon emission levels are projected to be greater in the more urbanized eastern half of the country, where the ratio of automobile to truck travel is the highest.

- Although net hydrocarbon emissions are projected to decrease from 1975 to 2000 for all Federal Regions, the decrease is expected to be slower in the South Central and Mountain Regions (Federal Regions VI and VIII) than in other regions because of increases in emissions from industrial sources, most notably petroleum refining and storage.

4.5.1 Introduction

The term hydrocarbons (HC) represents a broad range of hydrocarbon compounds released to the environment in gaseous form (e.g., benzene, toluene). Unsaturated, or reactive hydrocarbon compounds interact with nitrogen oxides in the presence of sunlight to produce photochemical oxidants, such as ozone (O_3) and peroxyacetylnitrates (PAN). These hydrocarbons exert indirect effects on health and welfare, in part as precursors to photochemical oxidants. Significant adverse health effects, such as high carcinogenic potential, are associated with certain subspecies of hydrocarbons (e.g., benzene). However, no single consistent set of health effects can be associated with hydrocarbons in general. The National Ambient Air Quality Standards (NAAQS) for hydrocarbons are expressed in terms of a 3-hour average measured during peak driving hours (6 a.m. to 9 a.m.), while oxidant levels are measured hourly.

Although only about 15 percent of total atmospheric hydrocarbon is produced through human activities;[22] these releases are significant because they are concentrated in densely populated areas and because they are more reactive. Much of the natural hydrocarbon is methane arising from bacterial decomposition in swamps and other water bodies. Such natural hydrocarbon is released over wide areas and is not usually a significant contributor to urban oxidant problems. The SEAS model measures only the releases caused by human activities.

The SEAS projections of total net hydrocarbon emissions for 1975 are about one-third the National Emissions Data System (NEDS) projections for 1976.[23] NEDS projected that in 1975 about 29.6 million tons of hydrocarbon were emitted from all sources, while SEAS projected that 13.5 million tons of hydrocarbon were emitted.

The largest single source of this discrepancy is solvent evaporation. Although SEAS estimates hydrocarbons from solvent production, it does not contain estimates for solvent evaporation during the use of the products. NEDS estimated over 8 million tons of hydrocarbon emissions from miscellaneous solvent use. Similarly, 2.8 million tons of hydrocarbons were produced by evaporation during chemical manufacturing in 1975 according to NEDS, while SEAS projections for these sources are under a million tons. The final major discrepancy is emissions from transportation. SEAS projected that 7.4 million tons of hydrocarbons were emitted from transportation activities, while NEDS projected that 13 million tons of hydrocarbons were emitted from transportation sources.

As a result of these discrepancies, forecasts of hydrocarbon emissions by SEAS are probably low in each projection year. NEDS projected that for each ton of solvent produced there is a ton of hydrocarbons emitted. Since SEAS does not project emissions from solvent evaporation, the SEAS forecasts of hydrocarbons will be low by the amount of solvent produced in each forecast year. Emissions of hydrocarbons from the chemical industry forecast by SEAS are probably less than half the actual emissions of hydrocarbons from that industry. Finally, SEAS projections of hydrocarbons from transportation activities are limited to exhaust pipe discharges, while NEDS includes emissions from additional sources such as manifold and lubricant evaporation. Thus the difference in hydrocarbons emissions between SEAS and NEDS will probably remain about constant over time.

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[22] American Chemical Society, Cleaning Our Environment: A Chemical Perspective, Second Edition, Washington, D.C., 1978, p. 124.

[23] U.S. Environmental Protection Agency, National Emissions Report, 1976, National Emissions Data System of the Aerometric and Emissions Reporting System, National Air Data Branch, Monitoring and Data Analysis. Research Triangle Park, N.C., August, 1979.

Methods to account for evaporative losses currently are being developed for SEAS, and will be part of the model by summer, 1980. This should close most of the gaps between the SEAS and NEDS data bases by accounting for emissions during the use of materials such as solvents as well as emissions from their manufacture. A new transportation model is also ready for use by SEAS. This model is designed to calculate accurate projections of emissions from transportation activities.

4.5.2 Emissions Trends for Hydrocarbons

The principal sources of net hydrocarbon emissions in 1975 are listed in Table 4-8. More than half are due to transportation, with automobile travel accounting for 60 percent and trucking, 40 percent. These releases, through interactions with nitrogen oxide emissions, probably contributed to major air quality problems, as more than three-fourths of the urban counties in the United States failed to attain the primary National Ambient Air Quality Standard for photochemical oxidants.[24]

Net hydrocarbon releases are projected in both scenarios to decline substantially between 1975 and 1985 and remain relatively

TABLE 4-8
PRINCIPAL SOURCES OF NET HYDROCARBON EMISSIONS
1975

Source	Net Emissions (10^6 Tons)	Percent of Total Net Emissions
Transportation	7.4	55
Auto	4.4	--
Truck	3.0	--
Paints	1.6	12
Petroleum Refining	1.4	11
Other	3.1	22
Total	13.5	100

[a] Sources each of which emits less than 6 percent of the total.

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[24] Federal Register, March 3, 1978, pp. 8692 ff.

constant thereafter. Trends in emissions from major sources for the High Growth Scenario are displayed in Figure 4-12. Much of the initial decline is in transportation emissions, reflecting the impact of compliance with present mobile source abatement requirements. In the 1985 to 2000 time period, improvements in emission controls would extend over the entire automobile fleet and further reduce hydrocarbon emissions. The use of water-based paints in place of solvent-based paints also would reduce emissions, as application of solvent-based paints releases hydrocarbons.

The only significant hydrocarbon source projected to generate increased pollutants throughout the 1975-2000 period is petroleum refining and storage. Improvements in abatement practices expected for this industry would retard but not halt the growth in net emissions resulting from rising petroleum demands. However, the expected shift away from liquid hydrocarbon fuels toward coal use could dampen growth in emissions.

In the Low Growth Scenario, net hydrocarbon discharges will be 15 and 25 percent lower than High Growth in 1985 and 2000, respectively. Discharges by major emission sources for both scenarios in 2000 are compared in Table 4-9. The source of the largest scenario difference is transportation, which is affected by the slower economic growth, higher energy prices, and other shifts assumed in the Low Growth Scenario. These factors combined, result in substantially lower transportation activity and hence, in lower mobile source emissions.

TABLE 4-9
SCENARIO COMPARISON OF NET NATIONAL HYDROCARBON EMISSIONS
2000

Source	High Growth Emissions (10^6 Tons)	Low Growth Emissions (10^6 Tons)	Scenario Difference[a] (Percent)
Transportation	4.1	2.6	-36.5
Paints	1.0	0.8	-20.9
Petroleum Refining	2.0	1.6	-20.0
Other	3.0	2.6	-13.3
Total	10.1	7.6	-24.9

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[a] Scenario Difference = $\frac{\text{(Low Growth - High Growth)}}{\text{High Growth}}$

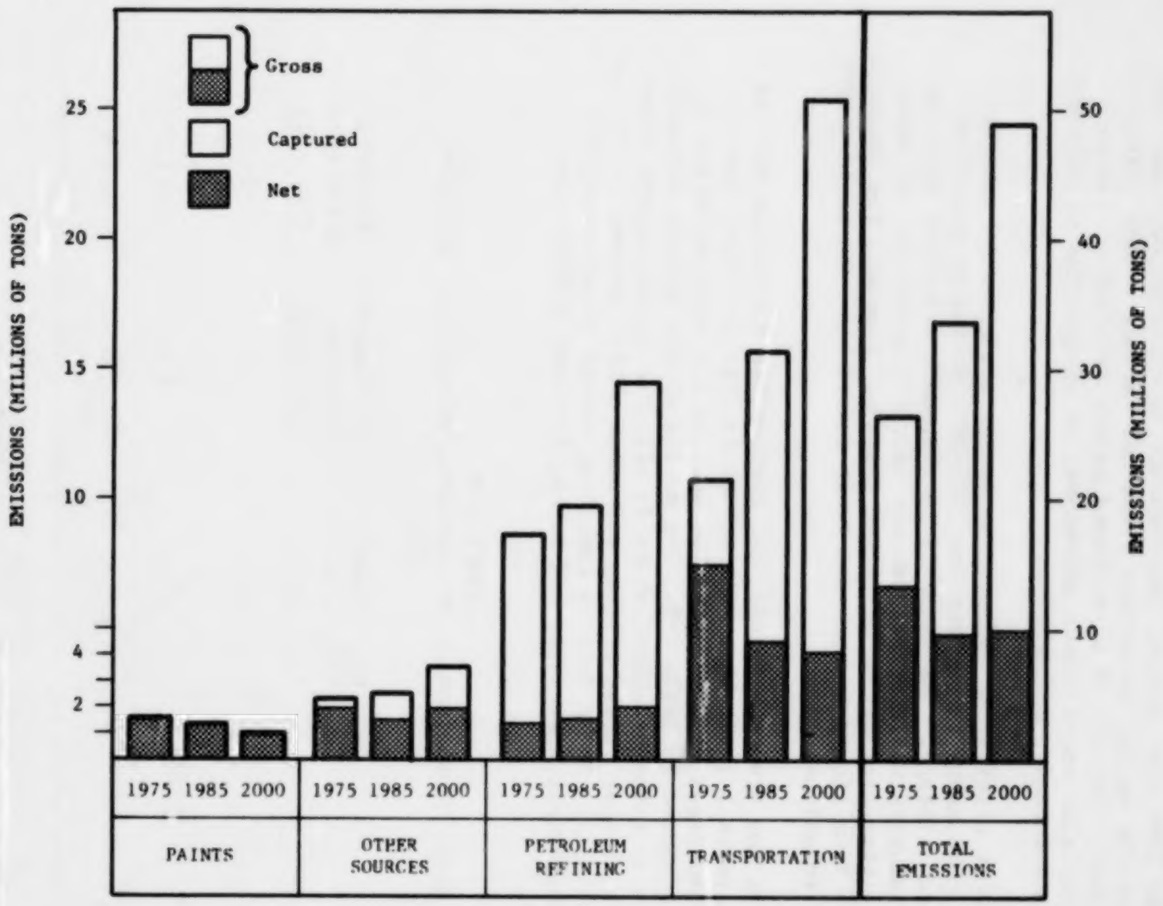

FIGURE 4-12
TRENDS IN HYDROCARBON EMISSIONS, BY SOURCE
HIGH GROWTH SCENARIO
1975, 1985, 2000

As was the case nationally, emission reductions in each region would result largely from implementing more stringent motor vehicle emission controls. Since automobiles are controlled more closely than trucks, the improvements in emission levels are more pronounced in the more urbanized areas east of the Mississippi, where auto travel constitutes a relatively high share of total motor vehicle miles traveled.

The changes in HC emissions projected to occur in each region are illustrated in Figure 4-13. In the South Central and Mountain Regions (Federal Regions VI and VIII), total net emissions decrease at a slower rate than in other regions as a result of increases in emissions from major industrial sources. In both regions, emissions from petroleum refining and storage were a substantial component of 1975 discharges. Because of continued growth in product demand, emissions are projected to increase slightly, even though abatement technology is implemented. Emission increases would occur in Region VI as a result of growth in the paint and organic chemical industries.

4.6 CARBON MONOXIDE AND DIOXIDE

HIGHLIGHTS OF SECTION 4.6

- Although less than 10 percent of global atmospheric carbon monoxide results from human activity, as much as 98 percent of carbon monoxide in urban areas results from human sources, especially automobile travel.

- The buildup of carbon dioxide from combustion activity may eventually exceed the earth's assimilative capacity, resulting in long-range adverse effects on climate. Both carbon monoxide and carbon dioxide are environmentally hazardous.

- Current air quality standards regulate carbon monoxide emissions but not carbon dioxide emissions.

- Pollution control devices, engine design improvements, and the use of mass transit alternatives to personal auto travel are expected to reduce auto emissions more than two-thirds from 1975 to 2000. Truck emissions, which are less strictly regulated, are expected to decline by only one-third between 1975 and 2000.

- Carbon monoxide emissions from all sources are expected to be cut in half from 1975 to 2000 under high economic growth and to decrease 40 percent under lower economic growth primarily because of reduced transportation emissions.

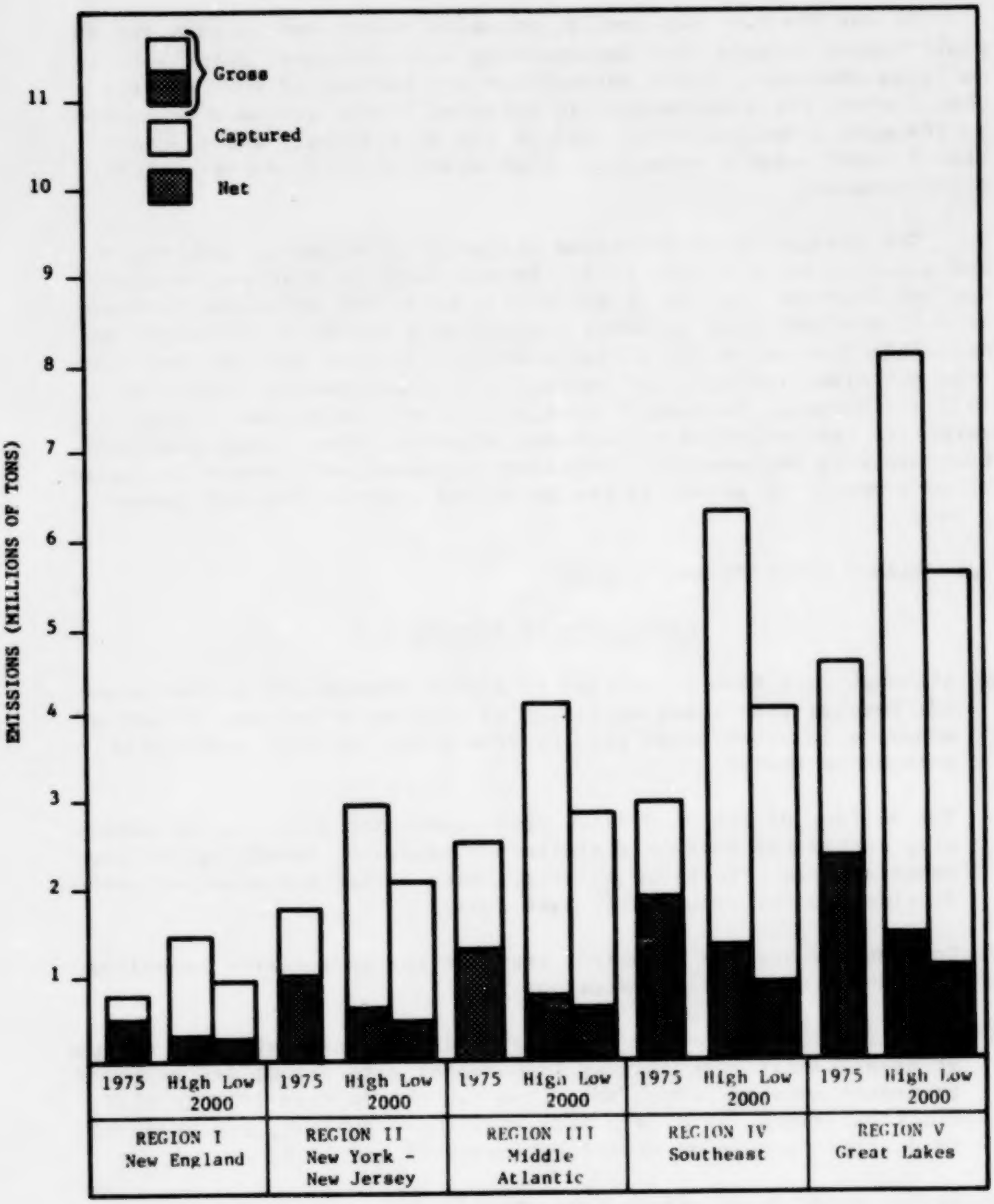

FIGURE 4-13
TRENDS IN REGIONAL HYDROCARBON EMISSIONS
1975 AND 2000

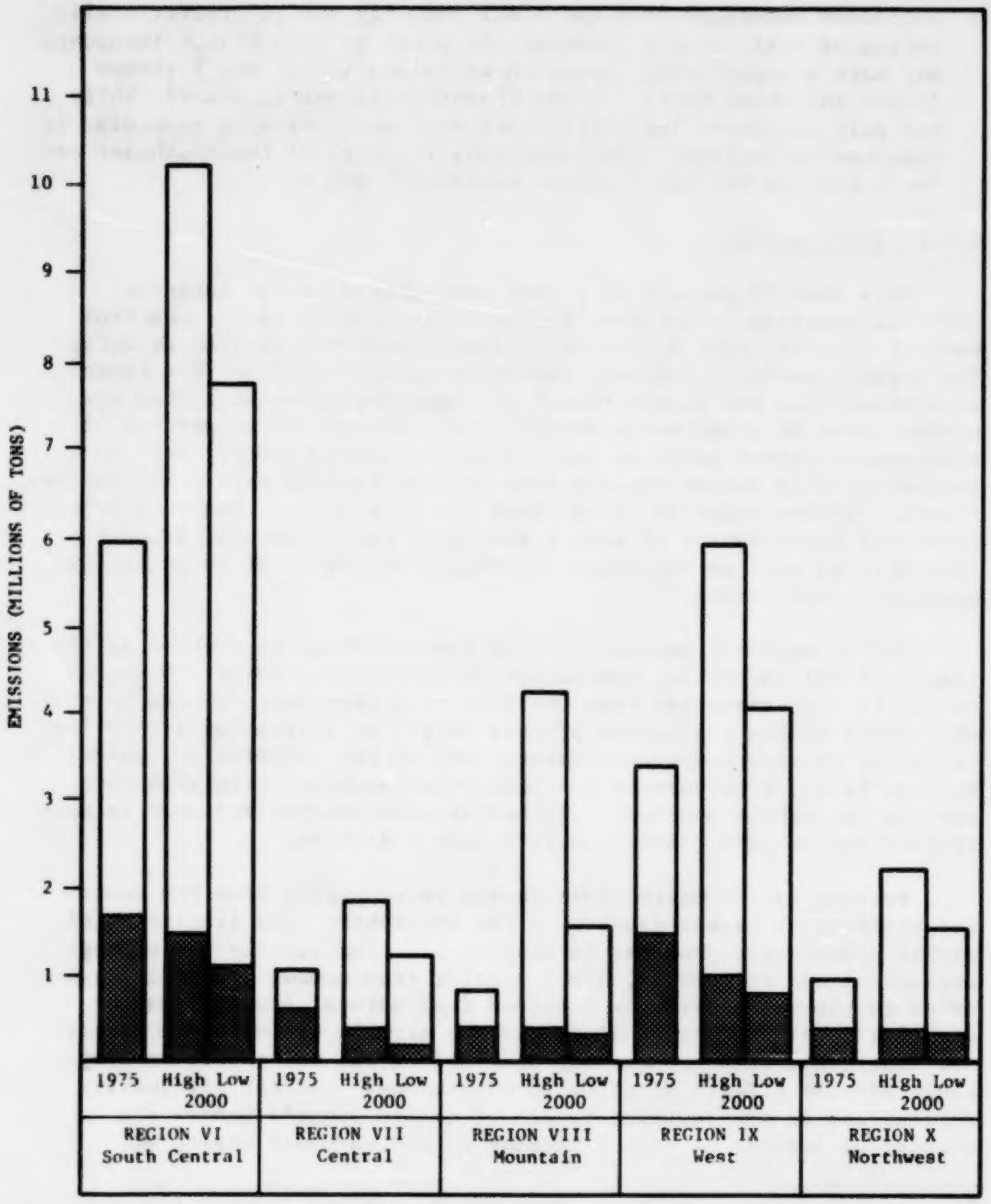

FIGURE 4-13
CONTINUED

- Increased emissions from the steel industry due to greater utilization of basic oxygen furnaces (in place of open hearth furnaces) may have a significant impact on emissions in the New York-New Jersey and Great Lakes Regions (Federal Regions II and V), while the pulp and paper industry, which has no CO emission controls, is expected to increase local emissions in parts of the Southeast and South Central Regions (Federal Regions IV and VI).

4.6.1 Introduction

More than 90 percent of global atmospheric carbon monoxide (CO)--an odorless, colorless, and relatively inert gas--comes from natural sources, such as the oxidation of methane produced by decaying organic matter. However, carbon monoxide emissions from human activities pose the larger threat to human health because they are concentrated in urban environments, where as much as 98 percent of atmospheric carbon monoxide results from human activity. Over 90 percent of this amount results from transportation, mainly automobile travel. Carbon monoxide is believed to cause adverse health effects, including exacerbation of angina and other cardiovascular disease symptoms, as well as impairment of vision and physical coordination, headaches, and nausea.[25]

Carbon monoxide emissions, like hydrocarbons, are formed as the result of the incomplete combustion of hydrocarbon fuels. Measures to control emissions can take the form of either improvements in the efficiency of the combustion process (e.g., by increasing air-to-fuel ratios or raising combustor temperature) or the addition of control devices (e.g., afterburners for industrial sources, catalytic converters for mobile sources). In either case, carbon monoxide is controlled through its conversion into carbon dioxide.

Further environmental hazards may be resulting from the continued build-up of carbon dioxide in the atmosphere (see discussion of global atmospheric problems in Chapter 5). The rapidly increasing production and release of carbon dioxide from combustion activity, added to the carbon dioxide released from natural sources, may be creating total loadings that exceed the earth's assimilative capacity. There has been speculation that this trend may result in long-range adverse effects on climatic conditions. Current air quality regulations do not restrict levels of carbon dioxide generation because no impacts of carbon dioxide levels on human health or welfare have yet been proven. The increases in carbon dioxide resulting from carbon monoxide controls are not expected to greatly exacerbate the conditions described above. Even if all the man-made carbon monoxide emissions reported in 1975 (estimated at 93 million tons) were transformed through combustion or catalytic oxidation into carbon dioxide, the carbon dioxide emissions emitted from this source would represent only a small fraction of the total estimated carbon dioxide loading.

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[25] Stoker, H.S. and S.L. Seager, Environmental Chemistry: Air and Water Pollution, Glenview, Illinois, 1976. Also, American Chemical Society, Cleaning Our Environment: A Chemical Perspective, Washington, D.C., 1978.

Mobile source (transportation) emissions data used in SEAS were derived from a recent EPA study.[26] The SEAS estimates of total national carbon dioxide emissions based on this data were about 10 percent higher than the estimates for 1973 from the National Emission Data System,[27] a difference readily explained by the slight differences in assumptions and accounting conventions.

4.6.2 Emissions Trends for Carbon Monoxide

The application of pollution control devices for transportation equipment, coupled with improved engine design, is expected to result in a 70 percent reduction in auto emissions between 1975 and 2000 (Table 4-10). However, emissions from trucks, under more lenient mobile source standards, are expected to decline by only one-third between 1975 and 2000.

In the High Growth Scenario, total net carbon monoxide emissions are projected to be cut in half between 1975 and 1985, and then level off. Under Low Growth conditions, reductions are expected to continue beyond 1985; this is attributable to greater use of mass transit as alternatives to personal auto travel. In a comparison of the two scenarios by 2000, total net emissions are projected to be 30 percent lower in the Low Growth Scenario than in the High Growth, and automobile and truck emissions each would be about 35 percent lower as a result of assumed lower economic growth, high oil prices, and transportation modal shifts. The actual extent of these projected reductions will depend heavily on the implementation of control technologies.

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[26] U.S. Environmental Protection Agency, Compilation of Air Pollutant Factors, 2nd Ed., Document AP-42, Supplement No. 5, Washington, D.C., 1975.

[27] U.S. Environmental Protection Agency, 1973 National Emissions Report, National Emissions Data System of the Aerometric Emissions Reporting System, EPA-450/2-76-007, May 1976, p. 5. (The most recent data published in NEDS were not available for this analysis.)

TABLE 4-10
COMPARISON OF NET CARBON MONOXIDE EMISSIONS FROM HUMAN ACTIVITY
1975 and 2000

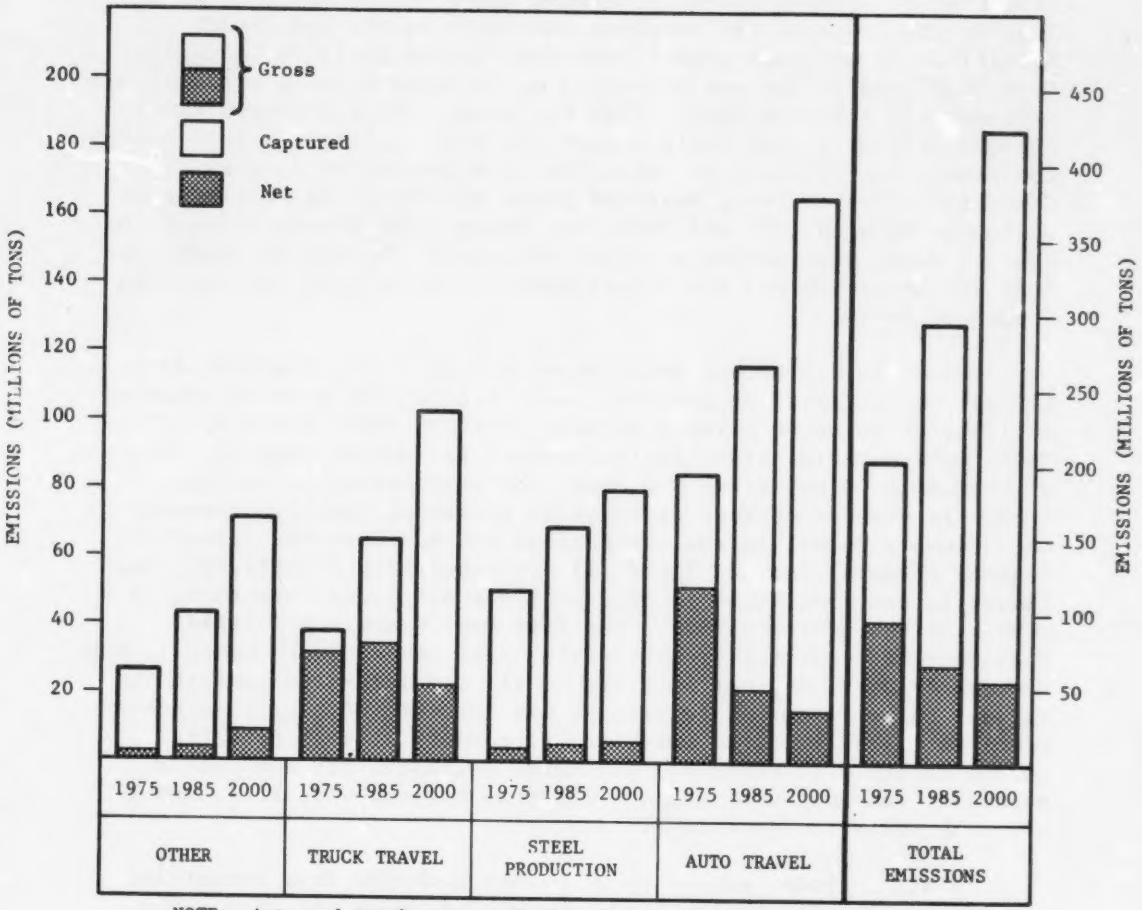
	1975		2000						
			High Growth			Low Growth			
Source	10^6 Tons	Percent of Total	10^6 Tons	Percent of 1975 Total	Percent of Total	10^6 Tons	Percent of 1975 Total	Percent of Total	Scenario Difference[a] (Percent)
Auto Travel	51.5	55	16.2	32	31	10.3	20	28	-37
Truck Travel	32.4	35	22.1	68	42	14.0	43	38	-37
Steel Production	4.6	5	6.5	141	12	5.4	116	15	-18
Other	4.7	5	7.8	166	15	7.2	153	19	- 9
Total	93.2	100	52.6	56	100	36.9	40	100	-30

[a] $$\text{Scenario Difference} = \frac{\text{(Low Growth - High Growth)}}{\text{High Growth}}$$

Net carbon monoxide emissions from manufacturing activities are expected to increase about 70 percent between 1975 and 2000 in the High Growth Scenario and increase one-third in the Low Growth Scenario. In the High Growth Scenario, carbon monoxide emissions from steel production are projected to increase by only about 40 percent between 1975 and 2000, with the bulk of this increase due to greater utilization of basic oxygen furnaces in place of open hearth furnaces. Carbon monoxide emissions from industrial sources other than steel (particularly pulp and paper manufacturing) are expected to double between 1975 and 2000, but these would remain a small component of national carbon monoxide emissions. Trends in emissions from all major sources are illustrated in Figure 4-14 for the High Growth Scenario.

Trends in net carbon monoxide emissions at the regional level reflect the national projections, with all regions showing emission declines of 40 to 60 percent between 1975 and 2000, assuming effective implementation of pollution control for mobile sources. Regional trends in CO emissions are shown for both scenarios in Figure 4-15. In view of current failures to attain air quality standards, the downward trends in the New England and New York-New Jersey Regions (Federal Regions I and II) are especially significant, even though current emissions in these regions are lower than those in a number of the other regions. The five most heavily populated regions--Middle Atlantic, Southeast, Great Lakes, South Central, and Western (Federal Regions III, IV, V, VI, and IX)--also exhibit the highest carbon monoxide emissions, and exposure of people in these areas to carbon monoxide emissions represents a large potential health hazard. In contrast, estimated emissions for the Central, Mountain, and Northwest Regions (Federal Regions VII, VIII, and X) are relatively insignificant.

In all regions, emissions of carbon monoxide from industrial sources are dwarfed by the large amounts of emissions from automobiles and trucks. However, trends in several regions are influenced by emissions projected for various industrial sources, notably steel production and pulp and paper manufacturing. Emissions from steel production would increase in the New York-New Jersey and the Southeast Regions (Federal Regions II and IV). In the Southeast Region the pulp and paper industry is projected to become a substantial carbon monoxide source by 2000, assuming that no pollution controls for carbon monoxide are required of this industry. Emissions would increase over 150 percent between 1975 and 2000 in the High Growth Scenario, and over 100 percent in the Low Growth Scenario, as illustrated in Figure 4-16. However, these increases would be more than offset by the expected large decreases in transportation emissions.



NOTE: Auto and truck gross emissions based on emission rates from uncontrolled pre-1968 vehicles. Engine deterioration based on average vehicle age of 5.99 years for autos, 7.15 years for trucks. Engine deterioration emission factor based upon pre-1968 vehicles.

FIGURE 4-14
TRENDS IN CARBON MONOXIDE EMISSIONS, BY SOURCE
HIGH GROWTH SCENARIO
1975, 1985, 2000

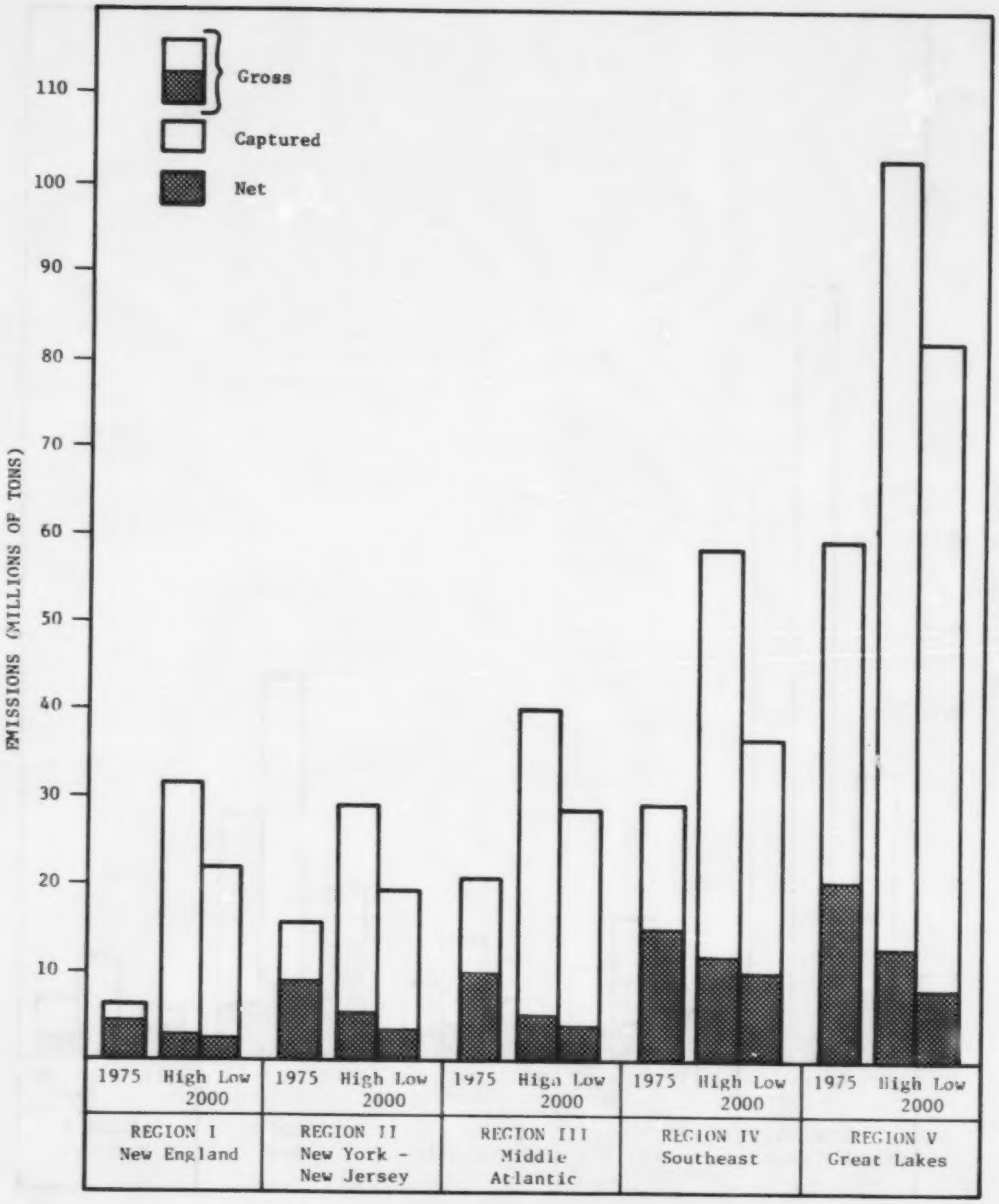


FIGURE 4-15
TRENDS IN REGIONAL CARBON MONOXIDE EMISSIONS
1975 AND 2000

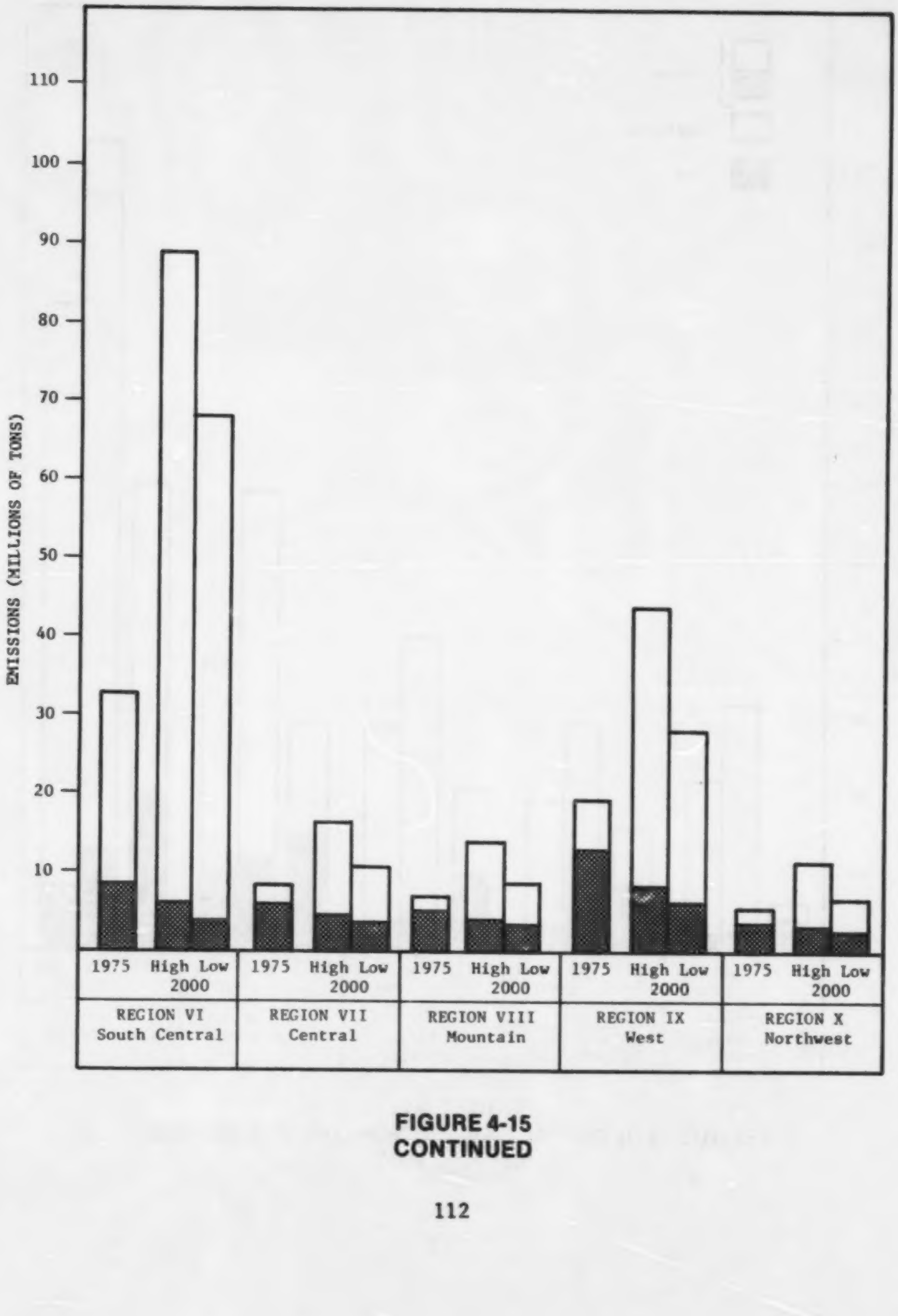


FIGURE 4-15
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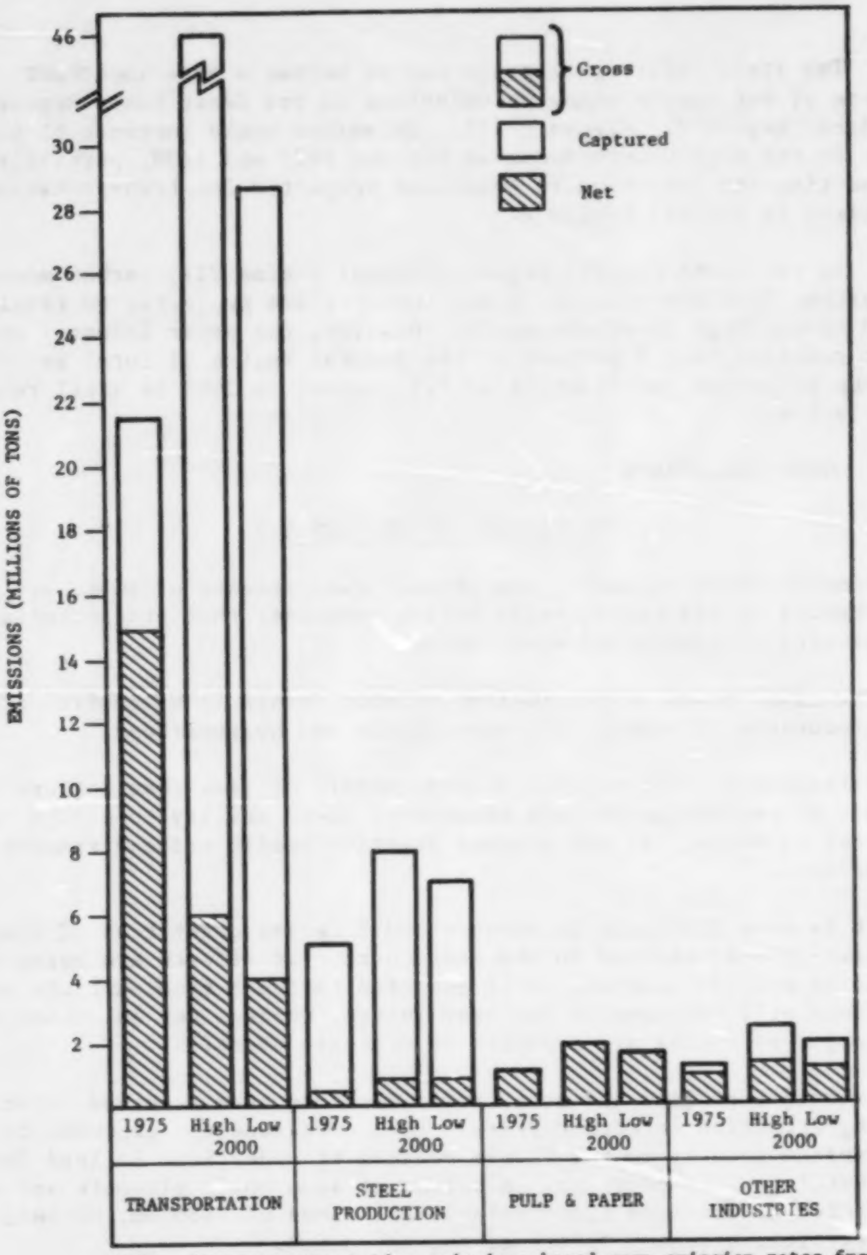


NOTE: Gross transportation emissions based upon emission rates from pre-1968 motor vehicles. Engine deterioration based on average vehicle age of 5.99 years for autos, and 7.15 years for trucks. Engine deterioration emission factor based upon pre-1968 vehicles.

FIGURE 4-16
CARBON MONOXIDE EMISSIONS, BY SOURCE
REGION IV
1975 AND 2000

The steel industry is projected to become a more important source of net carbon monoxide emissions in the Great Lakes Region (Federal Region V) (Figure 4-17). Emissions would increase 65 percent in the High Growth Scenario between 1975 and 2000, partially offsetting the reduction in emissions projected for transportation activity in Federal Region V.

In the South Central Region (Federal Region VI), carbon monoxide emissions from the pulp and paper industry are projected to triple by 2000 in the High Growth Scenario. However, the paper industry contributed less than 2 percent of the Federal Region VI total in 1975, so the projected contribution of 7.5 percent in 2000 is still relatively low.

4.7 OTHER POLLUTANTS

HIGHLIGHTS OF SECTION 4.7

- Photochemical oxidants, the primary constituents of smog, are chemically and biologically active compounds that are potentially harmful to health and environment.

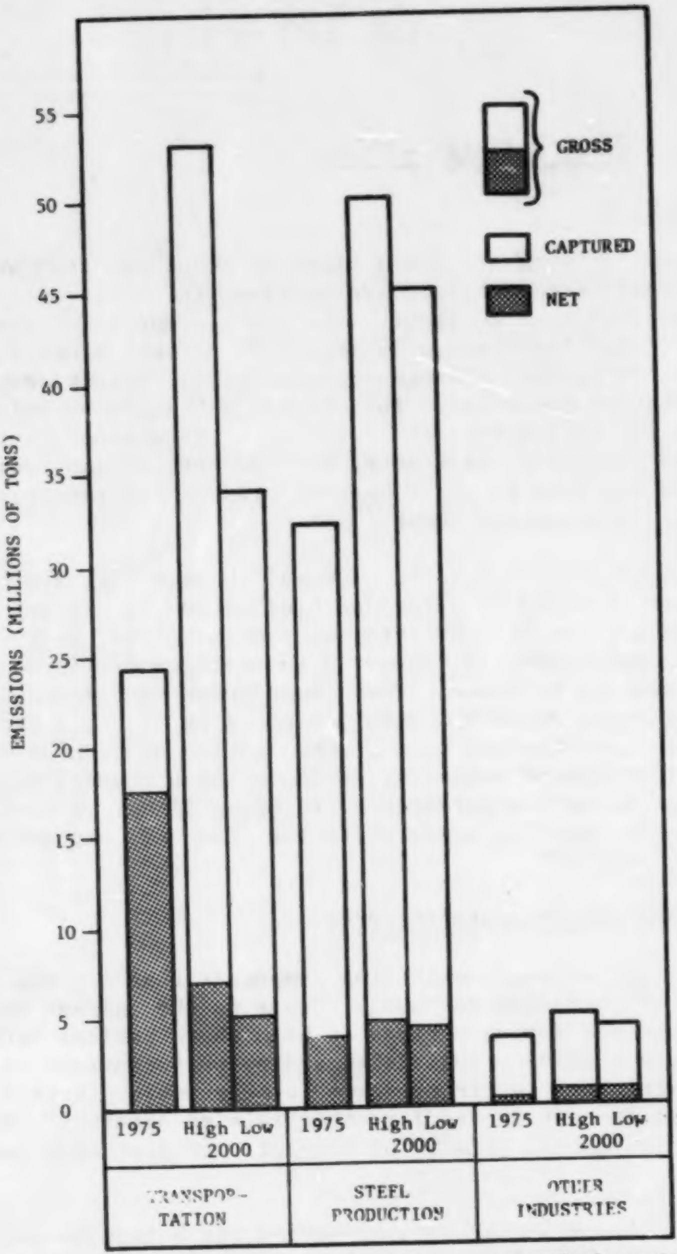
- The major means of controlling oxidant levels is by control of precursors of ozone: nitrogen oxides and hydrocarbons.

- Emissions of particulates with diameters of less than 5 microns are of particular concern because of their ability to escape control technologies, and produce negative health and environmental effects.

- It is very difficult to measure and forecast quantities of fine particulates emitted to the atmosphere, but efforts are being made to do so. In general, it is expected that net fine particle emissions will increase in the near future, whereas net emissions of larger particles are expected to decrease overall.

- Emissions of lead and other toxic elements have received increasing attention in recent years. Lead emissions are expected to decline greatly in the future because of reductions in lead fuel additives. In contrast, emissions of some toxic elements are expected to increase (particularly emissions of cadmium, nickel, selenium, arsenic, fluorine, and antimony).

- There is considerable concern regarding adverse health effects associated with exposure to high levels of lead and other toxic substances which are often present in the workplace. Of even greater concern, however, from an environmental point of view, are chronic exposures to low levels of such substances.



NOTE: Gross transportation emissions based upon emission rates from uncontrolled pre-1968 motor vehicle engine deterioration based upon an average vehicle age of 5.99 years for autos, and 7.15 years for truck engine deterioration emission factor based upon pre-1968 vehicles.

FIGURE 4-17
CARBON MONOXIDE EMISSIONS, BY SOURCE
REGION V
1975 AND 2000

4.7.1 Photochemical Oxidants - Ozone

Introduction

Photochemical oxidants are a class of compounds that are the products of reactions involving hydrocarbons (HC), nitrogen oxides (NO_x), oxygen (O_2), and sunlight. The toxic products of these photochemical reactions consist of about 90 percent ozone (O_3), and the remaining 10 percent nitrogen dioxide (NO_2), peroxyacetylnitrate, and other compounds. The complex mechanism by which they are produced is still a subject of research; in essence, critical levels of the precursor pollutants, nitrogen oxides and hydrocarbons, and a minimum level of sunlight must be present for the sequence of photochemical reactions to occur.[28]

Figure 4-18 illustrates the chemical changes that are observed when a mixture of nitrogen oxide and hydrocarbon is exposed to sunlight. There are two distinct stages. In the first, nitric oxide, a byproduct of combustion, is converted to nitrogen dioxide without any significant buildup of ozone. The second stage begins when almost all of the nitrogen oxide has been converted to nitrogen dioxide; this stage is characterized by the accumulation of ozone and other oxidant and non-oxidant products. Because these changes occur over several hours, ozone concentrations are often higher in downwind suburbs than in the specific areas where the chemical components are produced.

Health and Environmental Effects

Oxidants are strongly oxidizing compounds that are the primary constituents of photochemical smog. Ozone is the oxidant found in the largest amounts during periods of high photochemical activity. The current air quality standards regarding photochemical oxidants pertain to ozone because its presence is measurable, it is a major hazard, and it is a surrogate for other related agents.[29] Therefore, the environmental effects of oxidants are discussed only for ozone.

Ozone, a very reactive form of oxygen, is a broncho-pulmonary irritant that affects the mucus lining, other lung tissues, and

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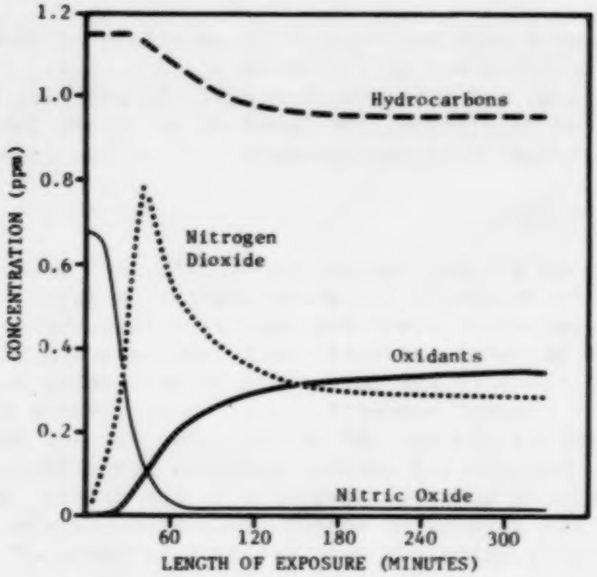
[28] Montana Ambient Air Quality Study: Photochemical Oxidants, Hydrocarbons, Nitrogen Oxides and Carbon Monoxide, Montana Air Quality Bureau, August 1978, pp. 1-2.

[29] U.S. Environmental Protection Agency, "National Ambient Air Quality Standard for Photochemical Oxidants," 44FR8220, February 1979.



Source: American Meteorological Society, Conference on Air Pollution Meteorology, Raleigh, North Carolina, April 1971. Used with permission.

FIGURE 4-18
CHEMICAL CHANGES OCCURING DURING EXPOSURE OF NITROGEN OXIDES AND HYDROCARBONS TO SIMULATED SUNLIGHT

respiratory functions in human beings and animals beginning at concentrations as low as 0.15 to 0.30 parts per million (ppm). Changes in lung function are characterized by such clinical symptoms as coughing, chest tightness, and lower chest soreness, and are a special hazard for asthmatic individuals.[30]

Vegetation may be damaged by ozone levels as low as 0.1 ppm. Visible leaf injury is the most readily detectable symptom of ozone exposure; decreases in growth and yield can occur without visible symptoms. The effects of ozone on vegetation vary with the concentration of the dose and length of exposure. A given dose is more damaging when applied over a short time period.[31]

Ozone may also damage many sensitive materials in what can be described as an acceleration of the aging process (e.g., rubber cracking, dye fading, and paint weathering). In contrast to the effects of ozone on vegetation, the level of materials damage appears to be directly correlated to the concentration of the ozone dose.[32]

Control Of Oxidants

Under the Clean Air Act Amendments of 1970, EPA established ambient air quality standards for photochemical oxidants. The initial primary and secondary standards specified that the hourly average concentration of total oxidants should not exceed 0.08 ppm. Compliance with the standards was determined by monitoring ozone levels as an indicator of oxidant concentration. In accordance with the provisions of Sections 108 and 109 of the Clean Air Act Amendments of 1977, EPA reviewed the air quality criteria for oxidants. The results of this review were two revisions in the oxidant standard: (1) the standard was revised to control only ozone levels and (2) the primary and secondary standards were set at 0.12 parts of ozone per million.[33]

Achievement of the above standards necessarily depends upon controls imposed upon the emission sources of the precursors (NO_x and HC) of photochemical oxidants. Reductions of emissions of nitrogen oxides and hydrocarbons are achieved through Federal and state programs formalized in regulations promulgated under the Clean Air Act. Typically, nitrogen oxide emissions are reduced to meet the annual nitrogen dioxide standard, then the hydrocarbon emissions are reduced enough to meet the ozone standard. The Federal programs provide for emissions control at the national level through the Federal Motor Vehicle Control Program, the Federal program for controlling aircraft emissions, National Emission Standards for Hazardous Air Pollutants, and New Source Performance Standards. The State Implementation Plans provide additional emission control measures designed to attain and maintain ambient air quality standards.

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[30] U.S. Environmental Protection Agency, Air Quality Criteria for Ozone and other Photochemical Oxidants, EPA 600/8-78-004, April 1978.

[31] Ibid.

[32] Ibid.

[33] U.S. Environmental Protection Agency, "National Ambient Air Quality Standard for Photochemical Oxidants," 44FR8220, February 1979.

The technological controls for nitrogen oxides and hydrocarbons being implemented to achieve compliance with the Clean Air Act through control of precursor agents were discussed in Sections 4.4 and 4.5.

4.7.2 Fine Particulates

Introduction

Fine particulates are defined for this discussion as airborne particles of solid or liquid matter having a diameter of less than 5 microns.[34] They are emitted by both natural and human-activity sources and can occur as either primary or secondary pollutants. Primary fine particles are emitted directly from a specific source, and secondary fine particles are formed in the atmosphere as products of the interaction of different gases or particles and gases. For example, carbonaceous primary fine particles are emitted directly from coal combustion. These particles are believed to contain toxic materials. However, a large part of the fine particulate problem has been attributed to these secondary particles. Among the substances identified as contributing to their formation are sulfur dioxide, nitrogen oxides, ammonia, and hydrocarbons. A pollutant may combine with oxygen, water, other naturally occurring elements in the air, or other pollutants to form fine particles such as sulfates, sulfuric acid particles, peroxyacetylnitrate (PAN), or other nitrates. These particles may have adverse health and environmental effects.

Fine particulate pollution has become a serious concern for several reasons:

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[34] There is no widely accepted size range defining fine particles. From a public health standpoint, particles of <15 microns are often termed "inhalable." In most discussions, the term "fine" is used to describe particles of less than 5 microns in diameter. In some cases, the upper size limit is defined as 2 or 3 microns.

- Fine particles tend to penetrate deep into the lungs; they are suspected of causing various adverse health effects.

- Primary fine particles are more difficult to control than larger particles. Generally, the smaller the particle, the more difficult it is to capture by filters, scrubbers, or other controls.

- Fine particles tend to remain airborne much longer than larger ones and can be transported over long distances. Thus, even if local controls are effective, fine particles transported from other less well-controlled areas can create a problem.

- Fine particles cause, or may cause, undesirable atmospheric effects.

Health and Environmental Effects

Because of their minute size, fine particulates often bypass the normal filtering mechanisms of the human respiratory system. The smallest particles (i.e., smaller than 1 micron) can penetrate deep into the lungs, irritating lung tissue or contributing to long-term disorders (e.g., silicosis, asbestosis, emphysema).

The greatest health risk posed by inhalation of fine particulate matter is from particles that are toxic themselves or that act as carriers of toxic trace substances. Most larger particles which impact the walls of the upper airways are cleared by the mucociliary transport mechanism; fine particles penetrate into the gas exchange area of the lung and are not subject to clearance by this mechanism. Consequently, chemically active particles may remain deposited deep within the lungs for months or even years, or they may be moved to the gastrointestinal tract.[35] Recently, there has been concern over the concentration of particulate matter, particularly inhalable particulates, in indoor areas. Sources such as tobacco smoke, household appliances, and building materials are currently being studied to evaluate possible health impacts. Since fine particulates are emitted from a wide variety of sources and may interact with different pollutants in the atmosphere, it is difficult to generalize about potential health effects. EPA has initiated a research program to study the health impacts of fine particles.[36]

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[35] Harrington, R.E., "Fine Particulates - The Misunderstood Air Pollutants," Journal of the Air Pollution Control Association, October 1974, pp. 928-929.

The presence of fine particulate matter in the atmosphere can also have adverse environmental effects. One of the most important is that fine particles reduce visibility by scattering and absorbing light. Particles of 1 micron diameter or less seem to be particularly significant as light-scattering agents. Many of these particles are sulfate compounds formed in the atmosphere from sulfur oxide emissions. Nitrate and carbonaceous aerosols are also suspected of contributing substantially to visibility problems.[37]

Another negative effect that might result from the light-scattering ability of fine particulates is a decrease in the amount of solar radiation that reaches the earth's surface. Theoretically, this could cause a decrease in the overall temperature of the atmosphere, with serious climatic consequences. Some observers feel that this tendency may be stronger than the "greenhouse effect" of rising global temperatures due to increasing concentrations of atmospheric carbon dioxide.[38] (See Chapter 5 for a discussion of the global implications of increasing carbon dioxide levels.)

Fine particles can also affect climatic conditions by acting as condensation nuclei. Heavy concentrations of atmospheric fine particles tend to increase the amount of precipitation and ice formation, in turn increasing the degree of cloudiness over the affected region. (See Chapter 5 for a discussion of global implications of atmospheric pollution.)

Control of Fine Particulate Emissions

Emissions of fine particulates can be controlled to some extent through the use of electrostatic precipitators, cyclone collectors, wet scrubbers, or baghouses. Generally, the efficiency of these techniques decreases as particle diameters become smaller than 2 microns. Baghouses are the most effective means of controlling fine particulate emissions; EPA tests have shown 95 percent collection efficiency for particles in the 0.1 to 4 micron size range.[39] Cyclone collectors, in contrast, have been tested at about 40 percent efficiency for fine particles.

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[36] Miller, et al., "Size Considerations for Establishing a Standard for Inhalable Particles," Journal of the Air Pollution Control Association, Vol. 29:610-15, June 1979.

[37] Ember, L.R., "Preserving Our Visibility Heritage," Environmental Science and Technology, March 1979, pp. 266-268.

[38] Stoker, H.S. and S. Seager, Environmental Chemistry: Air and Water Pollution, Scott, Foresman, and Company, Glenview, Illinois, 1976, p. 99.

[39] U.S. Environmental Protection Agency, Energy/Environment III, EPA-600/9-78-002, EPA Decision Series, October 1978, pp. 325.

Since the various methods have different collection efficiencies in relation to particle size, combinations of techniques may yield higher levels of control than single techniques. For example, the use of scrubbers and electrostatic precipitators together often results in higher fine particle collection rates than either of the devices used individually.[40]

The Clean Air Act Amendments of 1977 require standards for total suspended particulates (TSP) to be reviewed and, if necessary, revised by December 1980. At present, there is no separate standard for fine particle emissions. The two main criteria for establishing a fine particulate standard would likely be health impacts and visibility impairment. Attainment of a national optical standard for visibility, which the Council on Environmental Quality has recommended,[41] would require greater control of fine particle emissions. The Environmental Protection Agency is now looking at possible fine particulate standards as part of a review of the TSP standard, but both a national optical standard and a national fine particle standard are regarded by EPA as difficult to establish at this time on the basis of present scientific information.[42]

Sources of Fine Particulates

Fine particulates are produced by many sources, with the largest quantities being emitted as a result of combustion. Since measuring quantities of microscopic particles in the atmosphere is very difficult, and since both primary and secondary formation must be accounted for, the amounts of natural fine particle formation cannot be reliably estimated.

It is possible, however, to estimate primary emissions from specific sources. In a 1974 survey,[43] emissions were estimated for the major point, area, and mobile sources responsible for fine particle pollution (Table 4-11). These data are now considered to be of limited reliability, but they are included here to provide a rough indication of the substantial significance of fine particle emissions.

Some of these data have been updated on a site-specific basis in an EPA data management system known as the Fine Particle Emissions Information System. Substantial measurement data exist for more than

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[40] U.S. Environmental Protection Agency, Energy/Environment III, EPA600/9-78-002, EPA Decision Series, October 1978, pp. 325.

[41] Ember, L.R., "Preserving Our Visibility Heritage," Environmental Science and Technology, March 1979, pp. 266-268.

[42] Ibid.

[43] Midwest Research Institute, Fine Particle Emission Inventory and Control Survey, EPA-450/3-74-040, January 1974.

TABLE 4-11
MAJOR SOURCES OF FINE PARTICLE EMISSIONS
1972

(10^3 TONS/YEAR)

Source	Size Range (Microns)	
	.01-3	3.01-7
Wildfires	2160	—
Coal-Fired Electric Utilities	1080	780
Crushed Stone Industry	—	870
Motor Vehicles	—	760
Iron and Steel Industry	480	<10
Kraft Pulp Mills	410	90
Ferroalloy Production	280	20
Agricultural Burning	260	<10
Fuel Oil Combustion	190	—
Industrial Coal Combustion	160	270

Source: Midwest Research Institute, Fine Particle Emission Inventory and Control Survey, EPA-450/3-74-040, January 1974.

150 stationary sources, although these data do not provide a basis for estimating emissions for entire source categories or for national or regional totals.

Except for the crushed stone industry, all the major sources for which estimates are available are combustion-related. Data for some sources, such as fugitive dust and sea-salt aerosols, are scanty or unavailable. Thus, it is difficult to make very reliable conclusions about source contributions to total fine particle loadings in the atmosphere.

An area of concern over sources of fine particle emissions is the expected rapid increase in the use of diesel automobile engines. Most particulates produced by diesel engines are less than 0.5 micron in diameter--easily inhaled deep into the lungs, where they may remain for some time. Since diesel engines also produce a large number of organic compounds, some of which are known to be toxic or carcinogenic, their fine particle emission could constitute a significant public health hazard. The adsorption of toxic compounds on fine particle surfaces and penetration of the particles into the respiratory system are under study,[44] as are associated health effects.[45]

Emission Trends for Fine Particulates

As mentioned, it is very difficult to estimate the quantity of fine particle emissions from different sources. EPA's data base, FPEIS, contains detailed information on certain aspects of emissions from individual stationary facilities, but information on quantities of emissions is limited. For these reasons, the SEAS model does not make projections of fine particle emissions in the future. As the FPEIS data are expanded, such projections should become feasible.

4.7.3 Lead

Introduction

Lead is a toxic metal that has been the subject of increasing concern in recent years because of its potential for harm to human health. Current world production has been estimated to exceed 3.5 million tons per year.

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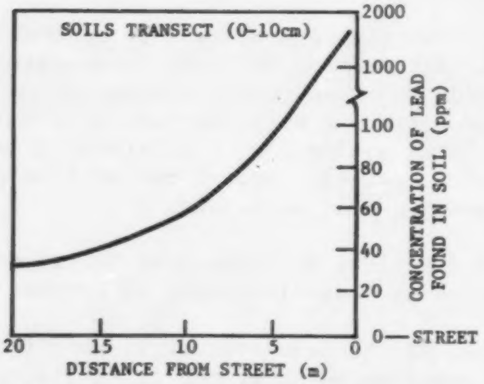
[44] Ember, L., "The Diesel Dilemma," Environment, Vol. 21, March 1979.

[45] Miller et al., "Size Consideration for Establishing a Standard for Inhalation Particles," Journal of the Air Pollution Control Association, Vol. 29:610-615, June 1979.

Health and Environmental Effects

Human health effects from lead pertain mainly to blood heme formation, kidneys, and the central nervous system. About 95 percent of the total body lead burden is stored in bone. This portion is in equilibrium with mobile lead circulating in the blood or present in other soft tissues such as the kidney. The mobile lead component in blood can cause shortened red-cell life span at blood concentrations of 50 to 100 micrograms per 100 grams of blood (0.5 to 1 part per million).[46] Reductions in blood hemoglobin levels and neurobehavioral deficits reflecting central nervous system damage have been demonstrated to occur starting at blood lead concentrations of approximately 4,050 micrograms per 100 grams of blood.[47]

Exposure to lead emissions near roadways is a potential hazard for people living or working in such environments for long periods of time. The soil buildup of lead near a roadway with high traffic volume is illustrated in Figure 4-19. This correlates to atmospheric lead concentrations that are encountered near roadways. Typically, soil lead concentrations declined to background levels within 50



Source: Rolfe, G. and A. Haney, An Ecosystem Analysis of Environmental Contamination by Lead, University of Illinois, Institute for Environmental Studies, Champaign-Urbana, Illinois, August 1975. Used with permission.

FIGURE 4-19
SOIL TRANSECT OF HIGH-TRAFFIC-VOLUME STREET

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[46] National Academy of Sciences, LEAD: Airborne Lead in Perspective, Washington, D.C., 1972.

[47] U.S. Environmental Protection Agency, Air Quality Criteria for Lead, EPA 600/8-77-017, December 1977.

meters of high traffic roadways.[48] People chronically exposed to heavily traveled roads may develop potentially damaging lead concentrations in their blood.

What happens to lead emitted to the environment is not well understood, but it appears that most lead cycled through the atmosphere has a residence time of 7 to 30 days in the air.[49] The ecologic flow of lead cycling in the biosphere is shown in Figure 4-20.

Lead affects plants such as maize at tissue concentrations of about 100 parts per million, with photosynthesis being depressed.[50] These responses are reached only in atmospheric concentrations far above current conditions.

Laboratory tests with mammals reveal that highest lead accumulations occur most in skeleton and kidney tissues, and can adversely affect blood heme synthesis. Concentrations necessary to cause such damage result mainly from the direct ingestion of lead with food. This may be a hazard for some domestic animals grazing near roadways.

Control Measures and Regulatory Status

A number of techniques can be used to control lead emissions. One approach is to set ambient air quality standards designed to limit emissions from major sources. Another is to regulate the content of lead in gasoline. A third method is to use nonleaded gasoline in motor vehicles equipped with catalytic converters. This last method protects the catalytic control device from damage and also helps reduce automotive lead emissions.

An ambient air quality lead standard of 1.5 micrograms per cubic meter (quarterly average) was initiated in October 1978.

The regulation of the lead content of gasoline applies to the entire supply of gasoline being produced. A limitation is placed on the quantity of lead that can be added to the total amount of gasoline being produced by a refinery. Thus, if a refinery produces mostly unleaded gasoline, it is allowed to have a relatively high lead

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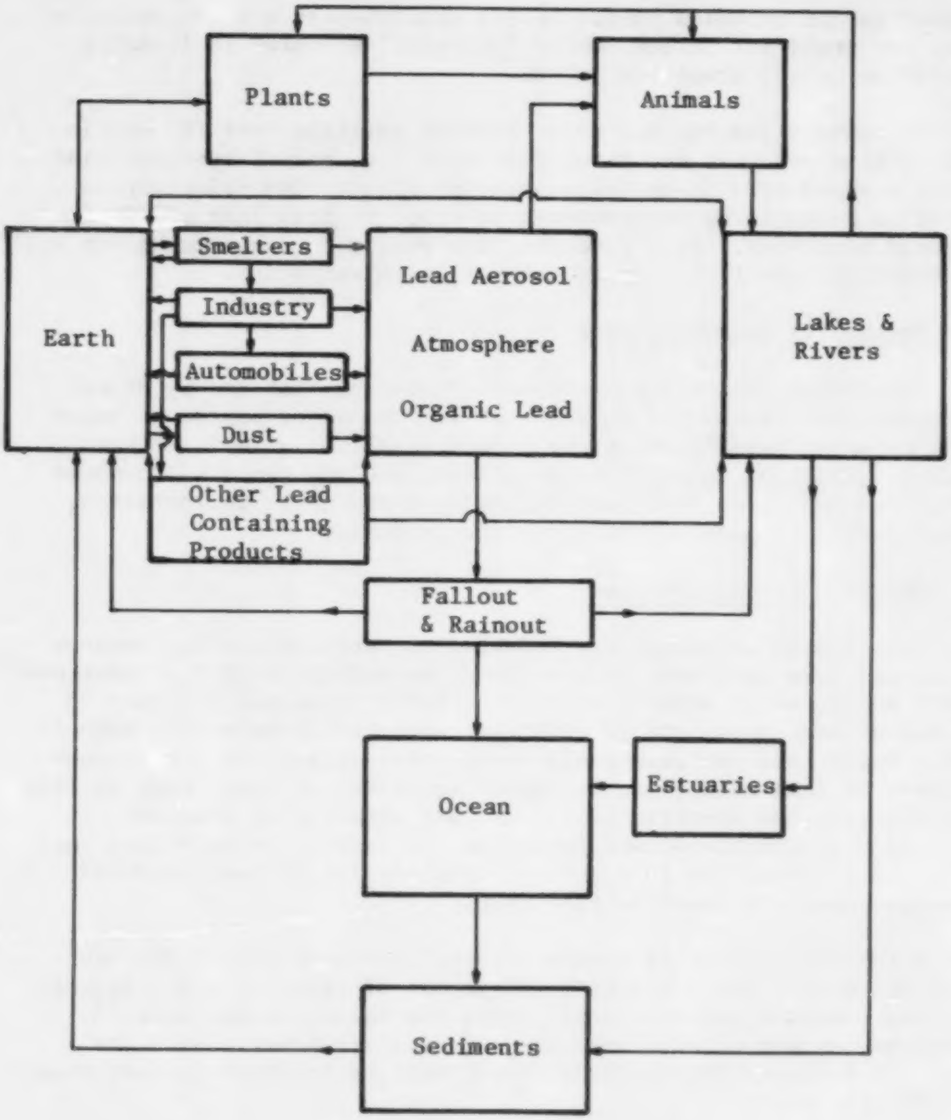
[48] Rolfe, G., and Haney, A., An Ecosystem Analysis of Environmental Contamination by Lead, University of Illinois, Institute for Environmental Studies, Champaign-Urbana, Illinois, August 1975.

[49] U.S. Environmental Protection Agency, Office of Research and Development, Air Quality Criteria for Lead, EPA 600/8-0173, Washington, D.C., 1978.

[50] National Academy of Sciences, Lead: Airborne Lead in Perspective, Washington, D.C., 1972.


Plants
Animals
Earth
Smelters
Industry
Automobiles
Dust
Other Lead Containing Products
Lead Aerosol
Atmosphere
Organic Lead
Lakes & Rivers
Fallout & Rainout
Ocean
Estuaries
Sediments

Source: National Academy of Sciences, Lead: Airborne Lead in Perspective, Washington, D.C., 1972.

FIGURE 4-20
ECOLOGICAL FLOW CHART OF LEAD SHOWING POTENTIAL CYCLIC PATHWAYS

content in its unleaded fuel. Leaded gasoline has a lead content of up to two grams per gallon, while "unleaded" gasoline is formally restricted to .05 grams per gallon.[51]

Emission standards for point sources emitting over 100 metric tons of lead per year are being developed for special consideration in the revised 1979 State Implementation Plans. Control measures center on controlling particulates in order to trap lead and lead compound particles. Most processes are expected to use baghouses and electrostatic precipitators to control these emissions.

Sources of Lead Emissions

Sources of lead air emissions projected by SEAS and by other estimates are illustrated in Table 4-12. The major source of emissions is motor vehicles that use leaded gasoline as fuel. Other sources, important in certain localities, include waste oil combustion, lead smelters, petroleum refining, solid waste incineration, electric utility plants, and gray iron production.

Emission Trends for Lead

Future lead emissions are expected to decrease sharply because of reduced lead additives in gasoline. According to SEAS projections (Table 4-12), motor vehicle emissions, which accounted for over 95 percent of lead emissions in 1975, are expected to be nearly zero in 2000. While this decrease would reduce overall ambient air concentrations of lead significantly, other emissions of lead, such as from lead smelters and electric utilities, are expected to increase, in both the High and Low Growth Scenarios. A typical primary lead smelter can emit from 5 to 15 pounds of lead per ton of lead produced depending upon the controls installed.[52]

A typical coal-fired electric power generator (1,000 MWe capacity) emits from about 670 to 1,200 pounds of lead per year, depending upon emission controls, coal type, and boiler design used.[53] Increased numbers of lead smelters and electric power plants are likely to increase ambient lead concentrations in areas located near such facilities.

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[51] Bureau of National Affairs, Environment Reporter, Washington, D.C., April 1978.

[52] U.S. Environmental Protection Agency, Office of Air and Water Programs, Emission Study of Industrial Sources of Lead Air Pollutants 1970, Research Triangle Park, North Carolina, 1973.

[53] Radian Corporation, Coal-Fired Power Plant Trace Element Study, Vol. 1, Austin, Texas, 1975.

TABLE 4-12
COMPARISONS OF ESTIMATES OF NET LEAD EMISSIONS
1975 and 2000
(10^3 tons)

	SEAS			Other References		
		2000				
Source	1975	High Growth	Low Growth	EPA: 1975 Data[a]	EPA: 1973 Data[b]	NAS: 1968 Data[c]
Copper Smelting	.003	.005	.005	.60	.90	
Lead Smelting	1.7	3.95	4.85	1.15	2.75	1.0
Electric Utilities	.70	.75	.80			
Highway Emissions	219.0	-0-	-0-	142.0	d	181.0
Industrial Combustion	.25	.10	.20			
Waste Oil Combustion				10.4		
Solid Waste Incin.				1.65	.30	
Gray Iron Production				1.10	1.40	
Iron and Steel				.85	.15	
Lead Alkyl Manufacture				1.00	.80	.80
Petroleum Refining					1.25	
Zinc Smelting					.25	
Ore Crushing				.50	.35	
Other Metallurgical				.25		.50
Type Metal				.45		
Portland Cement				.30		
Pigments				.10		
Other				.35	1.10	1.0
Total	221.6	4.80	5.85	161.25	9.2[d]	184.3

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[a] U. S. Environmental Protection Agency, Office of Research and Development, Air Quality Criteria for Lead, EPA-600/8-0173, Washington, D.C., December, 1978.

[b] Goldberg, A.S., A Survey of Emissions and Controls for Hazardous and Other Pollutants, U.S. Environmental Protection Agency, Air Pollution Technology Branch, Technology Division, Office of Research and Monitoring, Washington, D.C., 1973.

[c] National Academy of Sciences, Lead: Airborne Lead in Perspective, Washington, D.C., 1972.

[d] Highway emissions not included.

4.7.4 Trace Elements

Introduction

Scientific interest in trace element emissions into the atmosphere has been increasing, due to indications that the particles may be critical sources of adverse human health effects requiring better monitoring and control. Although the list of trace elements of potential concern is substantial, reliable data collection on the current sources of trace emissions has only been accomplished for a handful of elements. In this section, the following trace elements will be discussed:

- Antimony
- Arsenic
- Asbestos
- Beryllium
- Cadmium
- Fluorine
- Manganese
- Mercury
- Nickel
- Selenium

Health and Environmental Effects

Trace elements can have toxic properties even in very small concentrations in the environment. Exposure to these substances can reduce crop productivity and harm animal life. The discovery of elevated levels of trace metals in water samples from several remote streams raises the concern over the effects of deposition from the atmosphere to the aquatic environment. Some toxic elements such as mercury and fluorine can accumulate in the human body to lethal dosage levels through the food chain. Atmospheric trace element concentrations can also indirectly affect pollutants (as in the case of manganese, whose presence serves as a catalyst, in the conversion of sulfur dioxide to sulfates). However, regulatory authorities are primarily concerned with the potential health effects of direct human exposure to toxic elements, particularly in the workplace or in areas surrounding high emission point sources such as smelters or utilities. Table 4-13 presents the currently defined atmospheric threshold limit values for the 10 trace elements examined in this section, and identifies potential health consequences of exposure to ambient concentrations above these limits.

Sources of Trace Element Emissions

Trace element emissions can be generated from three basic types of activity. Industries manufacturing products containing these elements (e.g., asbestos pipe, cadmium based pigments) may release emissions of trace elements during processing. As these goods are consumed and disposed of, further atmospheric releases may result from such diverse sources as product deterioration, paint or pigment overspray or incineration of waste products containing these

TABLE 4-13
HUMAN THRESHOLD LIMIT VALUES AND TOXIC EFFECTS OF TRACE ELEMENTS

Trace Element	Threshold Limit Value [a]	Toxic Effects
Antimony[b]	0.5 mg/m^3	Dermatitis, keratitis, conjunctivitis, nasal system ulceration.
Arsenic[b]	0.5 mg/m^3 (0.2 arsine)	Dermatitis, bronchitis, skin cancer, gastrointestinal disturbances, (arsenia), hemolysis with arsine inhalation, interference with cellular metabolism. Poisonous when injected or inhaled.
Asbestos[c]	2.0 fibers/xm^3 of air space based on fibers longer than 5 μm for 8 hours.	Asbestosis lung disease. Possible carcinogen.
Beryllium[d]	0.1 μg/m^3 for short-term acute effects, 0.01 to 0.1 μg/m^3 for 30-day average, 2.0 μg/m^3 in work place.	Pneumonitis, or chronic respiratory disease, dermatitis, berylliosis, conjunctivitis. Suspected carcinogen in humans: proven carcinogen in lab animals.
Cadmium[e]	1 μg/m^3 acute effects; below 0.1 μg/m^3 chronic effects still possible.	Pulmonary edema, emphysema, renal dysfunction.
Fluorine[b,f]	2 mg/m^3	Interferes with calcium metabolism and enzyme mechanisms, causing cellular poisoning. Very toxic to plants and grazing animals; it is recommended that forage for dairy cattle contain not more than 40 ppm of fluorine (annual average) to protect human health.

(Continued)

TABLE 4-13 (CONTINUED)

Trace Element	Threshold Limit Value	Toxic Effects
Manganese[g]	10-260 μg/m^3 chronic exposure, increased incidence of pneumonia; 30,000 μg/m^3 poisoning. Recommended standard is 0.006 μg/m^3.	Pneumonia, central nervous system damage. Acts as catalyst to convert SO_2 to sulfates in atmosphere.[h]
Mercury[i]	0.05 mg/m^3 for 8 hours.	Pneumonitis, bronchitis, chest pains, dyspnea or coughing. Chronic exposure causes central nervous system damage, tremors, and kidney damage. Can produce teratogenic effects. Has ability to concentrate through food chains.
Nickel[j]	3 ppm nickel carbonyl for 30-minute exposure; 1 ppb for 8 hours; 1 mg/m^3 for nickel (metal).	Lung damage, dermatitis. Possible lung and nasal cavity carcinogen.
Selenium[b]	0.2 mg/m^3	Gastrointestinal effects; respiratory tract and skin irritaion.

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[a] Threshold limit value refers to the highest concentration of a toxicant allowable to protect against potential health effects. The air concentrations are abbreviated here as follows:

μg/m^3 = micrograms per cubic meter

mg/m^3 = milligrams per cubic meter

ppm = parts per million

ppb = parts per billion

fibers/cm^3 = fibers per cubic centimeter

μm = micrometer

(Continued)

TABLE 4-13 CONCLUDED

[b] Oak Ridge National Laboratory, Environmental, Health, and Control Aspects of Coal Conversion, An Information Overview, Vol. 2, Oak Ridge, Tennessee, April 1977.

[c] U.S. Department of Health, Education, and Welfare, National Institute for Occupational Safety and Health, Occupational Exposure to Asbestos, Washington, D.C., 1972.

[d] U.S. Environmental Protection Agency, Proposed National Emission Standards for Hazardous Air Pollutants: Asbestos, Beryllium, Mercury, Research Triangle Park, North Carolina, December 1971.

[e] U.S. Environmental Protection Agency, Health Assessment Document for Cadmium, EPA-600/8-79-003, Research Triangle Park, North Carolina, September 1979.

[f] National Academy of Sciences, Committee on Biologic Effects of Atmospheric Pollutants, Fluorides, Washington, D.C., 1971.

[g] Environmental Health Research Center, Illinois State Institute for Environmental Quality, Airborne Manganese Health Effects and Recommended Standard, Chicago, Illinois, July 1975.

[h] Low recommended standard (compared to toxicity) for manganese is due to the catalytic effect of manganese to convert SO_2 to SO_4. It is therefore, important to reduce this pollutant to control sulfate formation.

[i] U.S. Department of Health, Education, and Welfare, National Institute for Occupational Safety ane Health, Occupational Exposure to Inorganic Mercury, Washington, D.C., 1973.

[j] National Academy of Sciences, Committee on Medical and Biologic Effects of Environmental Pollutants, Nickel, Washington, D.C. 1975.

elements. Finally, these elements appear as trace constituents in fuels (particularly coal and oil) and ferrous and non-ferrous metals, and may be emitted during the conversion of crude resources into primary products. The relative importance of these three categories varies significantly between elements, as indicated below. Table 4-14 identifies current demand patterns for eight of the studied trace elements. Available information on consumption trends for these elements is summarized below:

- Antimony is being increasingly used by the chemical industry in the production of flame retardants.

- Asbestos consumption is projected to increase from 60 to 70 percent between 1975 and 2000. The fastest growing use of asbestos is in the formation of asbestos cement sheet.[54]

- Beryllium consumption declined dramatically between 1967 and 1975 in all end-use categories. Nonetheless, a 1978 ORNL/EPA report projected a ten-fold increase in domestic beryllium production requirements between 1975 and 2000.[55]

- Cadmium demand is expected to about double over the forecast period.[56] The fastest growing use of cadmium in recent years has been in battery manufacturing. The use of cadmium in plastics production has declined steadily over the past decade.

- Fluorine consumption patterns have remained virtually unchanged between 1968-1977.

- Mercury use in paint and pesticide production has been severely curtailed as a result of recent EPA initiatives. Similar regulatory efforts have caused chemical manufacturers to shift the process technology used for chlor-alkali production away from the mercury cell process. Mercury use in battery manufacturing, however, appears to be increasing.[57]

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[54] U.S. Environmental Protection Agency, Chemical Market Input/Output Analysis of Selected Chemical Substances to Assess Sources of Environmental Contamintion: Task III, Asbestos, EPA 560/6-78-005, Washington, D.C., 1978.

[55] Oak Ridge National Laboratories and U.S. Environmental Protection Agency, Reviews of the Environmental Effects of Pollutants: VI Beryllium, EPA 600/1-78-026, Washington, D.C., 1978.

[56] U.S. Environmental Protection Agency, Office of Toxic Substances, Multimedia Levels of Cadmium, EPA 560/6-77-032, Washington, D.C., 1977.

[57] U.S. Environmental Protection Agency, Office of Energy, Minerals and Industry, An Assessment of Mercury Emissions from Fossil Fueled Power Plants, EPA 600/7-78-146, Washington, D.C., 1979.

TABLE 4-14
DEMAND PATTERNS FOR EIGHT TRACE ELEMENTS, 1975
(% OF TOTAL CONSUMPTION)

	Consumptive Use														
Element	**Battery MFG**	**Chemical Production**	**Construction Material**	**Ceramics/ Glass**	**Electronic Components**	**Electro-plating**	**Industrial Controls**	**Iron & Steel**	**Missile & Aerospace**	**Non-Ferrous Metals**	**Paints**	**Paving & Roofing**	**Pulp/ Paper**	**Transportation Equipment**	**Utilities**	**Other**
Antimony		35		5										45		15
Asbestos			55									10	10	10		15
Beryllium					15				20						55	10
Cadmium	15			20		25					20			15		5
Fluorine		35						40		20						5
Mercury	30	20					15				15					20
Nickel						20		45		10						25
Selenium		15		35	45											5

Note: Shares must exceed 5% for inclusion in tables.

Source: U.S. Bureau of Interior, Minerals in the U.S. Economy: Ten-Year Supply-Demand Profiles for Non-Fuel Mineral Commodities, 1968-1977, Washington, D.C., May 1979.

- Nickel exhibits anti-knock properties in gasoline and has been considered as a major fuel additive to replace lead.

- Selenium is being used in increasing amounts by the electronics industry because of its high conductive properties.

Table 4-15 examines the potential for indirect emissions of trace elements from primary metal processing and fuel combustion activities. Where available, the table indicates the average concentrations of these elements present in input ores and fuels. Given such data, and estimates of the efficiency of existing particulate and sulfur oxide controls in removing trace substances from stack gases, rough calculations of total indirect discharges can be developed. Materials balance approaches are often employed to estimate the distribution of the trace residuals between airborne, water-borne and land environments.

Table 4-16 indicates the relative importance of direct and indirect trace element emission sources to current residual discharges. For the seven pollutants listed, only asbestos and mercury have direct emissions that exceed discharges from fuel combustion and/or ore smelting. Consequently, for most trace elements, the effectiveness of emission control in future years is dependent on the total (and possibly fine) particulate regulatory requirements imposed on smelters and large boilers by Federal and state initiatives. The current status of trace element emission control is discussed below.

Control of Trace Element Emissions

Control of toxic trace element emissions is usually associated with the control of major pollutants. Most toxic emissions are in the form of particulates and are affected by the implementation of control devices like baghouses and electrostatic precipitators (ESP). Other toxic elements such as selenium, are closely associated with sulfur compounds and may be partially controlled by sulfur oxide scrubbing devices. The most common mechanisms used in trace element control are listed in Table 4-17.

The efficiency of trace element removal has sometimes been assumed to be equivalent to the effectiveness of overall particulate control. However, several recent studies have questioned this assumption. A large portion of trace emissions are associated with fine particle matter which may escape current control devices. A summary of available information on trace element control efficiencies is included below.

TABLE 4-15
TRACE ELEMENT CONSTITUENTS OF SELECTED ORES AND FUELS

	Material Analyzed					
Trace Elements	Coal	Oil	Copper Ore	Lead Ore	Zinc Ore	Municipal Waste
Arsenic[a]			0.2-5.2% As content	<0.1% As content	<0.1% As content	
Beryllium[b]	1.6 ppm	0.08 ppm				
Cadmium[b]	1.0 ppm (0.25-2.0)	(.07-.11 ppm) diesel (.42-.53 ppm) residual		.11 lbs/ton of lead processed	2.5 lbs/ton of zinc processed	(31-75 ppm) sewage sludge
Mercury[c]	0.21 ppm (.06-.23)	0.1 ppm (.002-10)				
Nickel[d]	$.33 \times 10^{-6}$ lb/lb coal burned	$.23-3 \times 10^{-3}$ lb/gal. of oil burned				
Selenium[e]	(2.76-3.36 ppm)	0.17 ppm (0.004-0.6 ppm)				

Sources: [a] U.S. Environmental Protection Agency, The Ecological Effects of Arsenic Emitted from Non-Ferrous Smelters, 1978.

[b] U.S. Environmental Protection Agency, Reviews of the Environmental Effects of Pollutants, Vol. IV and VI, 1977-8.

[c] U.S. Environmental Protection Agency, An Assessment of Mercury Emissions from Fossil Fueled Power Plants, 1979.

[d] U.S. Environmental Protection Agency, Human Exposure to Atmospheric Concentrations of Selected Chemicals: Attachment A-21, Research Triangle Park, N.C., 1980.

[e] National Academy of Sciences, Selenium, 1976.

TABLE 4-16
DISTRIBUTION OF CURRENT TRACE ELEMENT EMISSION SOURCES
(% OF TOTAL EMISSION)

Trace Element	Emission Category Extraction and Processing of Element	Primary Metals Processing	Fuel Combustion	Manufacture of Trace Element-Based Products	Consumption and Disposal of Trace Element-Based Products
Asbestos[a]	55			20	25
Beryllium[b,c]	<5	<5	95		NI
Cadmium[d]		40	45	5	10
Manganese[c]		40	20	40	NI
Mercury[e]		10	35	10	45
Nickel[c]	<5	5	90		NI
Selenium[f]	5	20	70	5	NI

Note: NI = Not Included.

Sources: [a] U.S. Environmental Protection Agency, Chemical Market Input/Output Analysis of Selected Chemical Substances to Assess Sources of Environmental Contamination: Task III. Asbestos, EPA 560/6-78-006, Washington, D.C., 1978.

[b] U.S. Environmental Protection Agency, Reviews of the Environmental Effects of Pollutants: VI Beryllium, EPA 600/1-78-026, Washington, D.C., 1978.

[c] U.S. Environmental Protection Agency, Human Exposure to Atmospheric Concentrations of Selected Chemicals: Attachment A-21, Research Triangle Park, North Carolina, 1980.

[d] U.S. Environmental Protection Agency, Multimedia Levels of Cadmium, EPA 560/6-77-032, Washington, D.C., 1977.

[e] U.S. Environmental Protection Agency, Minerals and Industry, An Assessment of Mercury Emissions from Fossil Fueled Power Plants, EPA 600/7-78-146, Washington, D.C., 1979.

[f] National Academy of Sciences, Committee of Medical and Biologic Effects of Environmental Pollutants, Selenium, Washington, D.C., 1976.

TABLE 4-17
CONTROL TECHNIQUES FOR TRACE ELEMENT EMISSIONS

Control Technique	Trace Element
Dry Mechnical Collectors (Cyclones)	Arsenic,[b] Beryllium,[c] Cadmium,[a] Fluorine[d] Mercury,[a]
Fabric Filters (Baghouses)	Arsenic,[b] Asbestos,[c] Beryllium,[c] Cadmium[a] Flourine,[d] Manganese,[a] Nickel,[a] Selenium[d]
Electrostatic Precipitators (ESP)	Arsenic,[b] Cadmium,[a] Flourine,[d] Manganese[a] Mercury,[a] Nickel,[a] Selenium[d]
Wet Scrubbers	Beryllium,[c] Cadmium,[a] Fluorine,[d] Manganese[a] Mercury,[a] Nickel,[a] Selenium[d]
Dust Control via Process Modifications	Asbestos,[c] Beryllium,[c] Cadmium,[a] Mercury[a]
Materials Substitution	Asbestos,[c] Fluorine[d]
High Efficiency Particulate Air (HEPA) Filters	Antimony,[a] Beryllium[c]

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[a] U.S. Environmental Protection Agency, Office of Air and Water Programs, Emission Factors for Trace Substances, Research Triangle Park, N.C., 1973.

[b] U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Air Pollution Assessment Report on Arsenic, Research Triangle Park, N.C., 1976.

[c] U.S. Environmental Protection Agency, Office of Air and Water Programs, Control Techniques for (Various Trace) Air Pollutants, Research Triangle Park, N.C., 1973.

[d] National Academy of Sciences, reports by the Committee on Medical and Biological Effects of Environmental Pollutants, 1971-1976.

- Arsenic emissions are reduced 33-50 percent through the application of dust control devices such as ESPs or baghouses. Further reductions in arsenic (As) discharges from the non-ferrous smelting industry may indirectly occur as a consequence of increased leaching of ores undertaken for sulfur oxide control.[58]

- Before controls were placed on emissions of beryllium, emissions near production facilities were 500 times higher than present levels. (This implies a 99.8 percent control efficiency).[59]

- The highest observed concentrations of airborne cadmium emissions occur in the finest particles (35 ppm in 1-2 m particles, 22 ppm in 3-5 m particles, 15 ppm in 7-11 m particles). Therefore, current fly ash controls will not remove cadmium as effectively as they remove total particulates.[60]

- A recent study indicates that ESPs have no appreciable effect on the level of mercury emissions, sulfur oxide scrubbers can achieve 33 percent removal, and baghouses can control 30-60 percent of emissions from power plants.[61]

- It has been estimated that 53 percent of the selenium found in coal is released to the atmosphere as volatilized selenium or on particulates too fine to be trapped by standard dust collectors.[62]

Industrial sources of trace elements have been analyzed by region in SEAS documentation, for seven elements.[63] Several trace elements appear to have regionally concentrated emissions. These concentrations are due in large part to the location of large smelting plants in these localities. Sources of trace emissions not documented in SEAS are not reflected in Figure 4-21.

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[58] U.S. Environmental Protection Agency, Office of Toxic Substances, The Ecological Effects of Arsenic Emitted from Nonferrous Smelters, EPA 560/6-77-011, Washington, D.C., February 1978.

[59] Oak Ridge National Laboratories and U.S. Environmental Protection Agency, Reviews of the Environmental Effects of Pollutants: VI, Beryllium, EPA 600/1/78-026, Washington, D.C., 1977.

[60] ORNL/Environmental Protection Agency, Reviews of the Environmental Effects of Pollutants: IV, Cadmium, Washington, D.C., 1977.

[61] U.S. Environmental Protection Agency, Office of Toxic Substances, An Assessment of Mercury Emissions from Fossil Fueled Power Plants, EPA 600/7/78-146, Washington, D.C., 1979.

[62] National Academy of Sciences, Committee of Medical and Biologic Effects of Environmental Pollutants, Selenium, Washington, D.C., 1976.

[63] International Research & Technology, Inc., Review and Validation of SEAS Toxic Data Base, Urban Systems Research and Engineering, Inc., International Research and Technology, Inc., McLean, Virginia, 1978.

Emission Trends for Trace Elements

Total emissions of six of the trace elements are postulated to increase after 1975:[64]

Trace Element	Source of Increase in Emissions
Antimony	Lead, copper, and zinc smelting
Arsenic	Lead, copper, and zinc smelting Pesticide compounds in agriculture
Cadmium	Lead, copper, and zinc smelting
Fluorine	Inorganic chemical manufacturing Electric utilities
Nickel	Electric utilities Industrial combustion
Selenium	Electric utilities

Total emissions of four of the trace elements are postulated to decrease after 1975:

Trace Element	Source of Decrease in Emissions
Asbestos	Controls on asbestos mining activity Materials substitution in final product manufacturing
Beryllium	Controls on emissions from fossil fuel combustion
Manganese	Controls on emissions from fossil fuel combustion
Mercury	Reduced use in chemicals, paints, and pesticide manufacture.

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[64] The MITRE Corporation, National Environmental Impact Projection No. 1, Consad Research, Inc., Control Data Corporation, International Research and Technology, Inc., The MITRE Corporation, McLean, Virginia, 1978.

FEDERAL REGION	TRACE ELEMENT						
	ARSENIC	BERYLLIUM	CADMIUM	FLUORINE	MERCURY	SELENIUM	MANGANESE
I. NEW ENGLAND	▨	▨	▨	▨	░	▨	▨
II. NEW YORK/ NEW JERSEY	□	▨	▨	░	░	▨	▨
III. MIDDLE ATLANTIC	▨	▨ **	□ *	▨	░	▨ **	▨ *
IV. SOUTHEAST	▨	▨	□	░ *	░ *	▨ **	▨ **
V. GREAT LAKES	▨	▨ *	□	▨	▨	▨ *	▨ *
VI. SOUTH CENTRAL	□	▨	□	░	░ **	□	▨
VII. CENTRAL	▨	▨	□	░	▨	▨	▨
VIII. MOUNTAIN	□ *	▨	□	░	▨	□	▨
IX. WEST	□	▨	▨	░	▨	□	▨
X. NORTHWEST	□	▥	□	░	░	□	░

▨	UTILITIES
▥	INDUSTRIAL COMBUSTION
□	NON-FERROUS METALS
░	INORGANIC CHEMICALS

* REGION EMITS BETWEEN 20% AND 30% OF THE NATIONAL TOTAL.
** REGION EMITS OVER 30% OF THE NATIONAL TOTAL.

Source: The MITRE Corporation, National Environmental Impact Projection No. 1, Consad Research Corp., Control Data Corp., International Research and Technology, Inc., The MITRE Corp., McLean, Virginia, December 1978.

FIGURE 4-21
MAJOR SOURCES OF TRACE ELEMENT EMISSIONS
BY REGION
1975

The above emission predictions are based upon emission sources documented in the SEAS system. Sufficient data were not available to make predictions for different scenarios.

Effects of Trace Element Emissions

Trace element emissions are small compared with other pollutants, but their relatively high toxicity significantly increases the severity of their potential impact on health and the environment. Although national levels may be comparatively low, toxic emissions from only a few sources could cause localized environmental degradation. This is especially the case with the primary metals industry. Nonferrous smelters are geographically concentrated in Arizona (for copper) and Pennsylvania (for zinc). Arsenic, cadmium, and antimony emission levels from these individual sources could cause local damage.

Most energy-related trace element emissions are associated with coal combustion. In spite of increased dependence upon coal for fuel, electric utility emissions are expected to be stable or to decline, depending upon the energy scenario assumptions, because of more efficient particulate emission control methods. They would generate a significant proportion of national emissions of selenium, manganese, beryllium, and nickel, with only selenium and nickel emissions expected to increase after 1975. However, although total emissions from utilities are forecast to decrease, there still may be localized problems. It is expected that trace element emissions from industrial combustion will be smaller and less locally concentrated than those from electrical utilities, and will therefore be of less environmental concern.

4.8 IMPLICATIONS OF AIR POLLUTANT EMISSIONS TRENDS

HIGHLIGHTS OF SECTION 4.8

- The projected reductions (15 to 25 percent) in particulate generation from human activities would be especially effective in lowering emission densities in the heavily populated Northeast and Midwest regions of the United States where the bulk of current ambient air quality violations occur. On the other hand, areas in the southwestern and western states that do not meet total suspended particulate standards would probably not show any significant improvement over time because of the substantial component of natural fugitive dust emissions as a source.

- Although total sulfur oxide emissions are projected to remain relatively constant over time, considerable change in local air quality can be expected. Western counties in the immediate vicinity of copper smelters, for example, can anticipate substantial improvement in air quality due to emission control requirements. Sulfur dioxide concentrations in the Northeast corridor will probably remain a problem through 2000, and some new local problem areas may arise in the South Central and Mountain Regions (Federal Regions VI and VIII) as a consequence of much higher utilization of coal.

- Ambient air quality problems resulting from excessive carbon monoxide and photochemical oxidant concentrations, which are primarily urban phenomena, are projected to be virtually eliminated by 2000 through the application of mobile source control technologies.
- Because of the projected increase in emissions of sulfur and nitrogen oxides, the incidence and severity of acidic precipitation are expected to increase over time.

4.8.1 Introduction

No single model exists that can translate estimates of emission tonnages into measures of ambient air quality. Many of the significant impacts on air quality result from the interaction and transformation of the various components of air pollutants. Given these factors, it is extremely difficult to generate precise estimates of likely trends for human exposures to specific air pollutants or mixes of air pollutants.

Even with more precise information on probable human exposure trends, it would be difficult to define the likely human health impacts with any degree of specificity.

Several studies[65] have attributed incidences of various respiratory disease (e.g., chronic bronchitis, emphysema, pneumonia, influenza, asthma) to atmospheric pollution in the form of particulates, for example, but correlation between these studies has not been good. Since factors such as occupational exposure, cigarette smoking, nutrition, and genetics also affect assessment of human health impacts, no one estimate of health impacts can be used with any certainty. However, calculations of long-term environmental effects should improve as more information is collected on the effects reported on human beings, animals, and vegetation from exposure to various air pollutants.[66]

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[65] Lave, L., and E. Seskin, Air Pollution and Human Health, John Hopkins University Press, 1977. Also, National Academy of Sciences, Air Quality and Stationary Source Emissions Control, March 1975. Also, Crocker, T. et al., Methods Development for Assessing Air Pollution Control Benefits, U.S. Environmental Protection Agency, February 1979.

Realizing these limitations, the objective in this section is to provide insights into the future nature of environmental problems, with the focus on trends at the Federal Region level, supplemented by detailed examination of some local conditions. Three analytical approaches were utilized as appropriate:

1) To estimate the general potential for human exposure to pollutants, projections of Federal Region net emission densities (in terms of tons of pollutant emitted per square mile of land area) were compared with projections of regional population density. These relationships were calculated for both 1975 and 2000, and under both economic growth scenarios.

2) Regional distributions of current ambient air quality violations were tabulated to identify critical local problem areas and emission sources. By attempting to correlate violations with particular pollutant sources, it was possible in some cases to infer the probable air quality impacts for a specific growth trend or regulatory initiative.

3) Wherever non-SEAS projections of ambient air quality were available, they were examined for compatibility with SEAS trend information. The principal sources of ambient projections were the Council on Environmental Quality annual reports.

Following the pollutant-by-pollutant analysis, Section 4.8.7 discusses the synergistic effects of air emissions (e.g., acid rain and photochemical oxidant formation).

SEAS projections are developed for a highly aggregated regional grid (i.e., the Federal Regions), thus the ability of the trend projections to portray local conditions is limited. The scenarios used in this analysis, as indicated in the assumptions section of this chapter, do not reflect changes in regional growth patterns or increased control-induced emission reductions that result from the non-attainment or PSD restrictions placed on particular localities. Therefore, where the discussion that follows indicates a potential for continuing ambient problems, in many cases these conditions can be effectively mitigated by these existing regulatory policies mandated in the 1977 Clean Air Act Amendments. However, since these additional control requirements will result in increased costs for emission sources and may inhibit future growth in the area, these problem areas seem to be worth identifying.

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[66] EPA's recently established Environmental Criteria and Assessment Office, Research Triangle Park, NC (ECAO/RTP) is collecting and critically assessing information on health impacts and other effects of various air pollutants. Such information is also being collected in a central data base sponsored by the Electric Power Research Institute, members of the nonferrous smelting industry, and Arthur D. Little, Inc., of Cambridge, Massachusetts.

4.8.2 Implications of Particulate Emission Trends

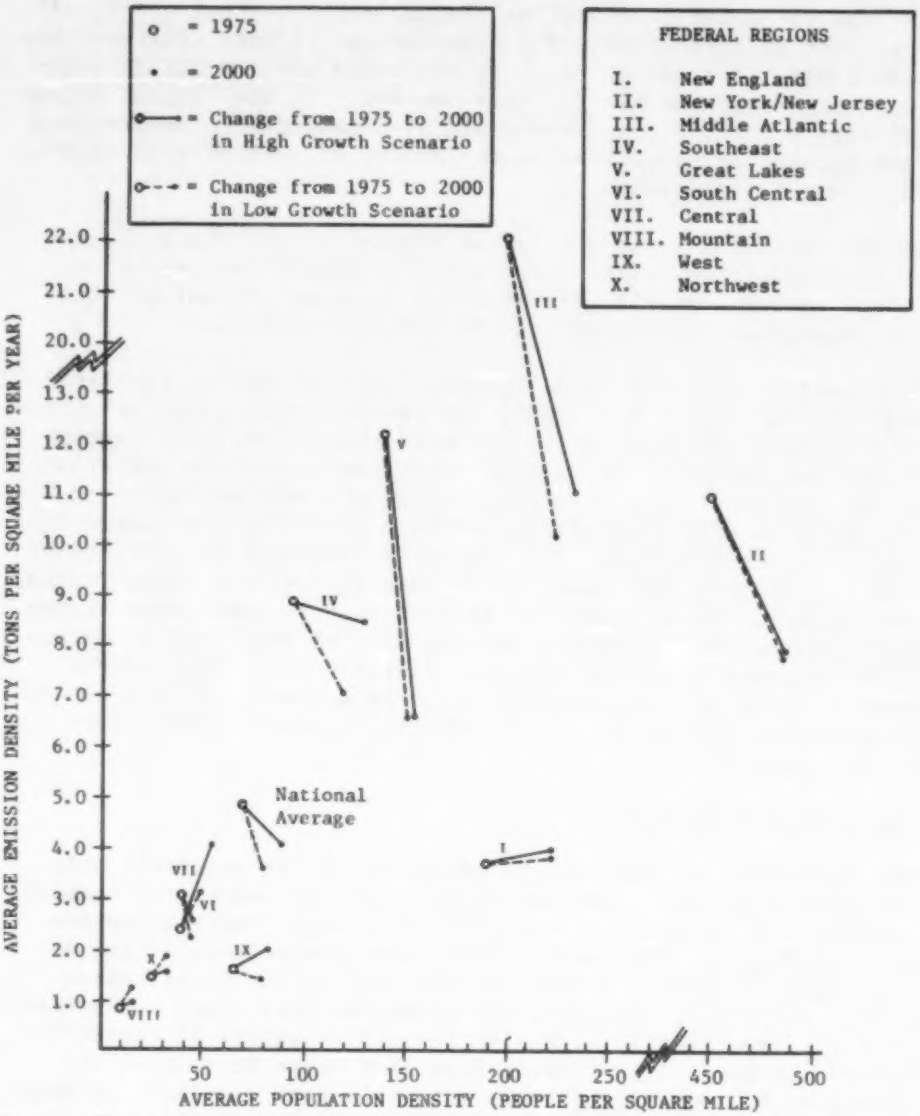
The trends for particulate emission densities and average population densities presented in Section 4.2 are plotted in Figure 4-22, relating net particulate emissions to the average number of people exposed. (This figure is based on SEAS data.) A more precise site-specific measurement of population exposure is preferable when discussing potential health impacts; nevertheless, trends presented in this figure may be used to identify areas where health impacts from net particulate emissions may be significant as projected by SEAS. A more detailed assessment would need to include naturally occurring particulates as well as fugitive dust from human activities such as agricultural tilling, construction, and dirt roads. These sources and their contribution to total suspended particulates are discussed separately later in this section.

Emission Densities

As shown in Figure 4-22, the Middle Atlantic Region (Federal Region III) had the highest emission density in 1975, with 22 tons of particulates per square mile. Emission densities in the Great Lakes, New York-New Jersey, and Southeast Regions (Federal Regions V, II, and IV) also were well above the national average of 5 tons per square mile.

The emissions in Federal Regions II, III, IV and V are especially significant because people are highly concentrated in these regions, and hence the potential for human health impact is greater. In the western and midwestern regions (Federal Regions VI through X), where average population densities tend to be below 70 people per square mile and average emission densities for human activities are below 4 tons per square mile, the potential for human health impacts is low.

Projected trends in net particulate emission density and population density from 1975 to 2000 are also illustrated in Figure 4-22 for the High and Low Growth Scenarios. For four of the most heavily populated regions of the country--the New York-New Jersey, Middle Atlantic, Southeast, and Great Lakes Regions (Federal Regions II,



Note: The particulate emission densities shown here are based on estimated emissions from human activity. They do not reflect the impact of fugitive dust on TSP concentrations. In some areas (e.g. Federal Regions VII, VIII, and IX) fugitive dust is a major contributor to ambient TSP levels.

FIGURE 4-22
TRENDS IN NET PARTICULATE EMISSION DENSITY VERSUS POPULATION DENSITY 1975 AND 2000
COUNTIES CONTAINING CLASS I PSD AREAS
POTENTIAL POPULATION EXPOSURE TO SULFUR OXIDE EMISSIONS

III, IV, and V)--emission densities are projected to decline significantly between 1975 and 2000. The expanded use of more efficient air pollution control devices on electric utilities and industrial boilers is primarily responsible for this decline. In the Central Region (Federal Region VII), net emissions are also expected to decline--in this case because of reductions in the amount of dust created by the construction materials industry.

In the remaining regions (Federal Regions I, VI, VIII, IX, and X), net particulate emissions are projected to increase over time. This is due in large part to the expected increase in coal utilization for industrial combustion and electricity generation.

This pattern of projections suggests that currently legislated standards for TSP (e.g., SIP, NSPS, and revised NSPS) could be effective in relieving TSP loadings in the most heavily polluted regions in the country. However, in regions where concentrations are relatively low, the reductions expected through the implementation of controls would be more than offset by large percentage increases in the rate of coal combustion. The resulting increases in particulate emissions may violate PSD standards in some of the many Class I areas in these regions. It is important to note that in areas such as the "sunbelt" regions that presently are not heavily populated or industrialized, emission densities are significantly lower than in the urbanized areas of the northeastern U.S. As a result, health impacts from emissions in the sunbelt will potentially remain lower, even though they increase.

Fugitive Dust Problems

The discussion of particulate emissions so far has dealt only with net emissions from human activities, such as industrial combustion, electricity generation, and stone crushing. These estimates were derived from the SEAS model, which uses projections of industrial activity and energy production and consumption to calculate atmospheric emissions. Studying the emissions from these activities is especially important in assessing the effectiveness of currently promulgated standards. Also, emissions from human activities are more likely to be composed of toxic materials than are fugitive dust emissions, and they therefore represent potentially greater impacts to human health.

Nevertheless, the standards for TSP do not differentiate among the pollutants' sources or measure toxicity levels. Particulate standards are stated in micrograms per cubic meter (ug/m^3). Fugitive dust is thus a component of TSP; in many areas it is the component that causes violations of primary ambient air quality standards.

Until a few years ago, fugitive dust was considered to be the result of unavoidable natural phenomena. However, EPA studies have shown that the most dominant fugitive sources in and around urban areas are those that result directly or indirectly from or during human activity. The major sources of fugitive emissions and dust are listed in Table 4-18.

EPA has estimated the total particulates generated as fugitive emissions and/or fugitive dust in those Air Quality Control Regions (AQCR's) violating either primary or secondary TSP standards [67] (i.e., non-attainment areas).[68] These particulate estimates which are not included in SEAS, are categorized as point or area sources and are grouped by Federal Regions in Table 4-19. Area sources are the most significant contributors to TSP, with the West, Great Lakes, and South Central Regions (Federal Regions IX, V, and VI) accounting for half the nation's area source emissions. Fugitive emissions and dust are also of concern in the New York-New Jersey and the Middle Atlantic Regions (Federal Regions II and III) because of the high densities of area source emissions.

The EPA study found that area sources of fugitive emissions and dust are the significant emitters of particulates in the majority of these non-attainment areas. In 92 percent of the 150 AQCRs violating TSP standards, area sources exceeded point source emissions. In fact, 58 of the 150 AQCRs had area source emissions that were 10 times greater than the point source emissions.

The data suggest a strong correlation between the incidence of TSP violations and area source emissions. However, this may not always be the case. If only one county within an AQCR is in violation, the AQCR is classified as being in violation. For example, AQCR 146 includes virtually the entire state of Nebraska (86 of its 93 counties). Since this is one of the largest AQCRs in the nation, it is not surprising that it has the highest estimate of area source emissions, 1235 x 10^3 tons per year. However, since only one county within the AQCR was actually in violation, it is difficult to say whether the area sources were in fact responsible. In other parts of the country, such as the Los Angeles area (AQCR 24), area source emissions from construction activity are very high and are likely to have caused the ambient violations in that area.

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[67] U.S. Environmental Protection Agency, Particulate Control for Fugitive Dust, EPA-600/7-78-071, April 1978.

[68] Non-attainment areas refer to counties or portions of counties currently classified as having ambient concentrations of a pollutant that are in excess of National Ambient Air Quality Standards.

TABLE 4-18
SOURCES OF FUGITIVE EMISSIONS AND DUST

Source	Description
o Agricultural Tilling	Major source of fugitive dust from human activity. May contain harmful pesticide residue.
o Construction Activity	Dust generated during the construction process and by wind action over the cleared land.
o Industrial Sources	Storage piles, materials handling equipment, pulverizing equipment, furnaces, and dryers. Dust escapes through vents, doors, windows, poorly maintained equipment, etc.
o Dirt Roads	Generally located in sparsely populated rural areas. Health impacts are relatively small.
o Paved Roads	Dust emitted to the air by motor vehicles--particulate matter from sand and dirt, wearing of vehicle parts, and engine exhaust.
o Off-road Motor Vehicles	Motorcycles, jeeps, other recreational vehicles. Localized impacts may be significant.
o Tailing Piles	Overburden and mining wastes stored in huge piles. Dust is carried to the air by wind action or during loading/unloading operations.
o Open Burning	Residential, commercial, industrial refuse burning, slash fires. NEDS data indicates this source is relatively small.
o Wind Erosion	Susceptibility of soils, rocks, etc. to erosion by wind action often increases when land is altered by human activity (e.g., unpaved roads, agricultural fields, mining and construction sites).

TABLE 4-19
POINT AND AREA SOURCES OF FUGITIVE EMISSIONS AND DUST IN AQCRS THAT DID NOT MEET TSP STANDARDS

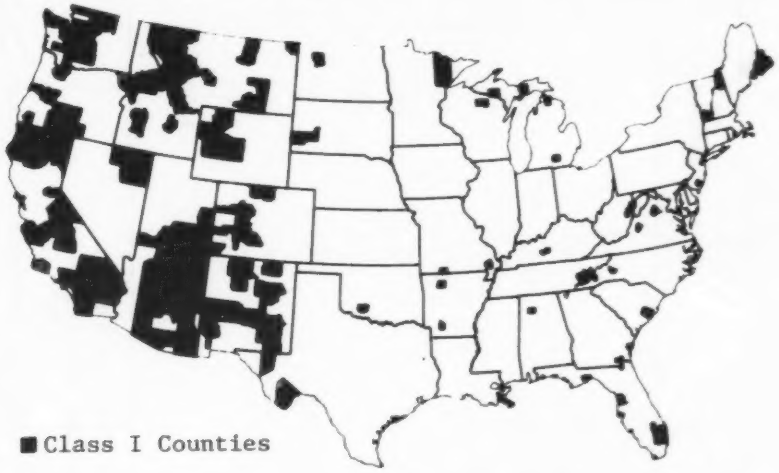
Region	Emissions (10^3 Tons/Yr)			Annual Emission Densities (Tons/mi^2)		
	Total Point Source	Total Industrial Source	Total Area Source	Point Source	Industrial Source	Area Source
I. New England	129	73	959	3.0	1.7	21.9
II. New York-New Jersey	301	100	2915	9.5	3.2	92.2
III. Middle Atlantic	1654	682	4907	15.8	6.5	46.9
IV. Southeast	2197	724	3074	13.5	4.4	18.9
V. Great Lakes	2255	965	7020	11.4	4.9	35.4
VI. South Central	552	292	6902	1.5	0.8	18.9
VII. Central	581	280	4118	3.2	1.5	22.4
VIII. Mountain	289	60	2286	0.7	0.1	55
IX. West	592	303	7855	1.6	0.8	21.0
X. Northwest	145	45	3370	0.6	0.2	14.0
Total	8695	3524	43406	4.1	1.7	20.5

AQCR = Air Quality Control Region
TSP = Total Suspended Particulates

Source: U.S. Environmental Protection Agency, Particulate Control for Fugitive Dust, EPA-600/7-78-071, Washington, D.C., April 1978.

The number of counties in violation of primary TSP standards is shown in Table 4-20. Comparison of the estimates of area source emissions in Table 4-19 and the violations in Table 4-20 suggests that area source emissions are significant in both urban and rural environments. Federal Regions IV, V, and IX account for over half the violations in the country, with Federal Region IX having the greatest percentage of counties in violation. Of interest is the fact that about two-fifths of the 236 violations were in rural counties. The area sources listed in Table 4-16 probably were responsible for the majority of rural ambient violations.

National Parks, Wilderness Areas, and other such pristine environments were classified as Class I areas by the Clean Air Act Amendments of 1977 in order to prevent any significant deterioration of air quality.[69] Counties that contain any of the 159 Class I areas currently designated are identified in Figure 4-23. The actual acreage, however, is less than 2 percent of the nation's total land area. As shown, the majority of counties containing Class I areas are located in the West. Increased coal combustion by power plants scheduled to come on line near these areas and industrial facilities switching from oil and gas to abundant supplies of Texas lignite and low-Btu high-ash western coals pose a potential threat to air quality in these western Class I areas.



Source: Data from U.S. Senate, Congressional Record, November 1, 1977, pp. S18375-6.

FIGURE 4-23
COUNTIES CONTAINING CLASS I PSD AREAS

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[69] Class I areas refer to national park lands, forests, and other natural areas stringently protected from air quality deterioration by the 1977 Clear Air Act Amendments.

TABLE 4-20
REGIONAL DISTRIBUTION OF COUNTIES WITH VIOLATIONS OF EPA PRIMARY STANDARDS FOR TOTAL SUSPENDED PARTICULATES
1975

Region	Counties in Violation			Number of Counties in Region	Percent of Counties in Violation
	Urban	Rural	Total		
I. New England	9	3	12	67	18
II. New York-New Jersey	6	0	6	83	7
III. Middle Atlantic	18	6	24	245	10
IV. Southeast	16	19	35	736	5
V. Great Lakes	44	22	66	524	13
VI. South Central	11	6	17	502	3
VII. Central	11	7	18	411	4
VIII. Mountain	9	5	14	291	5
IX. West	14	17	31	88	35
X. Northwest	7	6	13	119	11
Total	145	91	236	3066	8

Note: Counties not in violation of primary TSP standards were classified as "better than national standards," "does not meet secondary standards," or "cannot be classified."

Source: Based on U.S. Environmental Protection Agency SAROAD data system.

Conclusions

Expected reductions in point source net particulate emissions in the eastern United States (Federal Regions II, III, IV, and V) between 1975 and 2000 are significant because (a) those regions were the largest regional contributors of net particulates in 1975, and (b) they contain the most densely populated areas in the nation. In the rest of the country, particulate emissions increases associated with increased coal utilization are expected to exceed emission reductions achieved by environmental controls.

Even in areas where emissions trends appear good, many urban as well as rural areas may not be unable to attain national ambient air quality standards for TSP because of emissions from fugitive dust sources. The extent to which fugitive sources affect non-attainment areas cannot be completely quantified, but EPA estimates suggest they play a major role. Currently available control techniques for reducing emissions from area sources have had small influence in reducing fugitive emissions in most AQCRs. More information is needed on health impacts of particulates and on possible techniques for controlling the portion of fugitive dust arising from certain human activities.

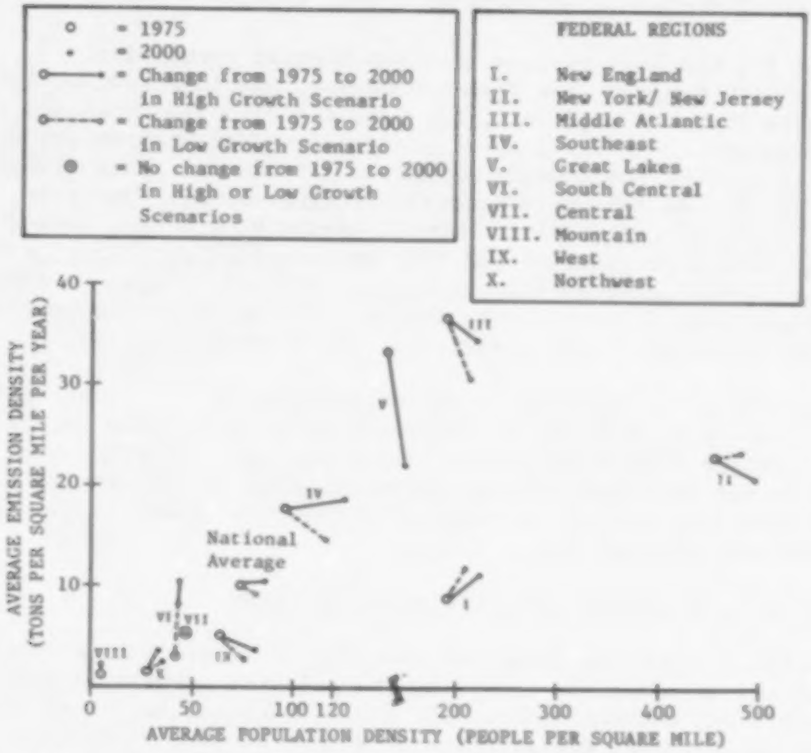
4.8.3 Implications of Sulfur Oxide Emission Trends

The emission trend projections for sulfur dioxide presented in Section 4.3 of this report estimate that total national sulfur oxides (SO_x) releases will remain fairly constant in the 1975-2000 period. The regional distribution of sulfur dioxide emissions, however, is projected to change substantially over the same time frame, primarily as a result of the construction of new coal-burning industrial facilities and power plants.

This section assesses the implications of future sulfur dioxide emission levels on human health and air quality on the basis of both a general analysis of regional emission densities and a more detailed examination of the sources of current non-attainment problems. The factors responsible for long-range transport phenomena are discussed separately, because of their importance as explanatory variables. This section of the report deals only with the direct implications of sulfur oxide emissions; the atmospheric interaction between sulfur oxide and particulates and the role of sulfur oxide in acid rain formation are both discussed in Section 4.8.7.

Emission Densities

The relationship between regional emission and population densities is graphically illustrated in Figure 4-24 for the years 1975 and



Note: The effects of atmospheric dispersion and long distance transport are not incorporated in this comparison. See text for details. Region X does not include Alaska in this figure.

FIGURE 4-24
POTENTIAL POPULATION EXPOSURE TO SULFUR OXIDE EMISSIONS

2000 under both High and Low Growth Scenarios. This comparison, although it does not account for pollutant transport between regions or locally varying concentrations, can provide a broad overview of the potential for human exposure to sulfur dioxide.

In 1975, the four regions with the highest population densities--New England, New York-New Jersey, Middle Atlantic, and Great Lakes (Federal Regions I, II, III, and V)--also contained some of the heaviest concentrations of projected sulfur dioxide emissions, thereby increasing the overall potential for adverse health impacts such as short- and long-term respiratory infections. Over time, the general levels of emissions in Federal Region V, and to a lesser extent in Federal Regions II and III, are expected to show significant improvement under both scenarios, as controls placed on existing coal-burning facilities begin to influence total emissions, while population grows at a rate slower than the national average.

Conversely, sulfur dioxide emission densities in the sunbelt states (Federal Regions IV and VI) would greatly increase over time and are coupled with rapid population expansion. Although these regions do not have many current sulfur dioxide violations, they may develop localized ambient problems as a result of their projected increased coal consumption.

Analysis of Current Non-Attainment Problems

Insights about the potential severity of future sulfur dioxide problems can be sought by analyzing the emission conditions believed responsible for current ambient air quality violations. Some information about regional distribution of sulfur dioxide violations in 1975 is shown in Table 4-21.[70]

Attempts to develop a correlation between ambient air quality problem areas, "hot spots", and the presence of major sulfur dioxide emission sources have met with only partial success. For example, the copper industry, although a minor source of national sulfur dioxide concentrations, 8 percent, has long been viewed as a critical source of localized problems. Of the 13 counties containing copper smelters, 10 were found to be in violation of primary ambient air quality standards; these included the bulk of air quality problem areas in the Mountain and Western Regions (Federal Regions VIII and IX). Since full compliance with current emission standards would greatly reduce smelter discharges of sulfur dioxide, air quality in these hot spots can be expected to improve over time.

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[70] Federal Register, March 3, 1978, pp. 8963-9059.

TABLE 4-21
REGIONAL DISTRIBUTION OF COUNTIES WITH VIOLATIONS OF EPA SULFUR DIOXIDE STANDARDS
1975

Region		Counties in Violation			Number of Counties in Region	Percent of Counties in Violation
		Urban[a]	Rural	Total		
I.	New England	1	1	2	67	3
II.	New York-New Jersey	1	-	1	83	1
III.	Middle Atlantic	4	4	8	245	3
IV.	Southeast	6	7	13	736	2
V.	Great Lakes	26	12	38	524	7
VI.	South Central	1	2	3	502	1
VII.	Central	3	-	3	411	1
VIII.	Mountain	2	4	6	291	2
IX.	West	2	5	7	88	8
X.	Northwest	1	2	3	119	3
	Total	47	37	84	3066	3

[a] Compliance information was not available for a number of heavily populated urban centers such as New York City, Chicago, and large portions of California.

Note: Counties not in violation of primary SO_2 standards were classified as "better than national standards," "does not meet secondary standards," or "cannot be classisifed."

Source: Based on U.S. Environmental Protection Agency SAROAD data system.

On the other hand, only 13 counties out of the 50 largest producers of coal-fired electricity were found to be currently out of compliance, despite the fact that coal power plants generated 60 percent of 1975 emissions.[71] High correlation does exist, however, between the overall concentration of power plant sites and the occurrence of ambient violations in the northeastern corridor of the United States.

Long-Range Transport

The long-range transport of sulfur dioxide emissions from upwind utilities and large industrial boilers has contributed to sulfur oxide concentrations in non-attainment areas in Ohio, Pennsylvania, New York and New England. Since future air quality in these areas is closely tied to the transport phenomenon, factors influencing pollutant transport are described below.

In recent years, the long-range transport of pollutants has been documented by many research programs.[72] Four basic factors affect the amount of transport that will occur during any given time frame:

1. Local air dispersion factors such as tall stacks, nighttime or cloudy conditions, constant windspeed and direction, and altitude.
2. Persistence of surface winds for 6 hours or more.
3. Prevailing winds at plant stack heights.
4. Large-scale meteorological conditions resulting from the relative movements of low- and high-pressure weather systems that can create large regional areas of stagnation.

When several emission sources are lined up in the same direction as the wind, pollution concentrations can be intensified many miles from the origin of the emissions. These conditions occur frequently in the northeastern United States where emissions from power plants located along the Ohio River Basin frequently become entrained in strong, prevailing southwest winds. The impacts of this transport have been felt as far away as western New York, New Hampshire, and Maine. These areas are receiving substantial amounts of sulfur oxides by wind transport, largely from emission sources in the Ohio

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[71] Estimates of coal-related electricity production (in 10^6 kWh) were derived from the Federal Power Commission's Form 67 data base for 1974.

[72] Several studies by the U.S. Environmental Protection Agency and the Electric Power Research Institute document the transport of sulfates. See Office of Technology Assessment, The Direct Use of Coal, Washington, D.C., January 1979, p. 199.

River Basin Area.[73] Hence, the large projected reductions in net emissions by 2000 in Federal Region V suggest that future transport of sulfur oxide to the northeast may decrease. This could help improve air quality in some areas of Pennsylvania and West Virginia, as well as in Federal Regions I and II, adding to the impact of local efforts to control sulfur oxide emissions, such as the abatement program currently under way in New York City.[74]

Other areas with strong potential for long-range sulfur oxide transport include the northern Great Plains, southeastern Utah, the southwest, and the Gulf Coast area in eastern Texas. The Great Plains area has many Class I regions vulnerable to emissions from energy and power plant development proposed in that vicinity, so facility siting must take these meteorological factors into account.

Similarly, energy conversion facilities planned for construction near the lignite fields of eastern Texas would be aligned approximately parallel to the prevailing southwest to northwest wind direction and could lead to intensified sulfur dioxide concentrations in the Southeast Region (Federal Region IV), Louisiana, and Arkansas.

4.8.4 Implications of Nitrogen Oxide Emission Trends

As of 1975, the direct implications of nitrogen oxide emissions were of much less environmental concern than the atmospheric transformation of nitrogen oxide into acidic ions or photochemical oxidants. Only eight counties in the country (five urban areas in California, Denver, and Chicago) were in violation of the long-term annual ambient standards for nitrogen oxides. Even with the increases in nitrogen oxide emission levels projected in these scenarios, the number of violators is not likely to increase greatly. The impacts of nitrogen oxide emission trends on smog and acid rain formation are discussed in Section 4.8.7.

4.8.5 Implications of Hydrocarbon Emission Trends

As in the case of nitrogen oxides, hydrocarbons are of concern mainly because of their role as precursors to oxidant formation. Consequently, the discussion on the implication of hydrocarbon emission trends has been incorporated into the oxidant discussion in Section 4.8.7.

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[73] Teknekron, Energy and Environmental Engineering Division, Transport and Fate and Gaseous Pollutants Associated With the National Energy Plan, Berkeley, California, 1977.

[74] U.S. Environmental Protection Agency, National Annual Air Quality and Emission Trends Report, NTIS PB-263922, Research Triangle Park, North Carolina 1976.

4.8.6 Implications of Carbon Monoxide Emission Trends

Air Quality Implications

As of August 1977, 164 counties in the United States were not in compliance with the primary NAAQS for carbon monoxide.[75] The pattern of violations, illustrated in Table 4-22, indicates that the predominant carbon monoxide problems are located in the New England, New York-New Jersey, Great Lakes, and West Regions (Federal Regions I, II, V, and IX) and are primarily an urban phenomenon. Although the counties in violation are only 5 percent of total U.S. counties, they contain over 40 percent of the American population. It should be noted that only one violation or two exceedances per year is necessary for a county to be considered out of compliance. In these urban environments, motor vehicles usually account for over 90 percent of carbon monoxide emissions; therefore, the effectiveness of mobile source control strategies is the key element in improving air quality.

Annual estimates of emissions, developed by EPA's Office of Air and Waste Management, suggest that carbon monoxide emissions from highway travel decreased by 15 percent between 1973 and 1976, as a result of the application of control devices.[76] Actual monitoring information from the EPA SAROAD data system on daily ambient conditions in 13 major cities indicate that the number of carbon monoxide violations decreased by 36 percent over the same period. Despite this overall trend, four of the cities monitored (Bakersfield, Fairbanks, Los Angeles, and Santa Barbara) showed no major improvement, primarily as a result of increases in total vehicle traffic. To offset increases in urban traffic, there is a need for additional measures such as inspection and maintenance programs and disincentives to commuting as part of transportation control plans.

As indicated in Section 4.6.2, national carbon monoxide emissions are projected to decrease about 45 percent between 1975 and 2000 under the High Growth Scenario, and about 60 percent under the Low Growth Scenario. These projected improvements stem from the assumption that the nation will attain full, on-schedule compliance with the mobile source standards set in 1977 for automobiles and trucks. By the 1982 model year, for example, new autos are expected to release about 3.4 grams of carbon monoxide per vehicle mile

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[75] Federal Register, March 3, 1978, pp. 8963-9059.

[76] U.S. Environmental Protection Agency, Office of Air and Waste Management, National Air Quality and Emissions Trends Report-1976, December 1977.

TABLE 4-22
REGIONAL DISTRIBUTION OF COUNTIES WITH VIOLATIONS OF CARBON MONOXIDE STANDARDS
1975

Region	Counties in Violation			Number of Counties in Region	Percent of Counties in Violation	Total Population at Risk (10^6)
	Urban	Rural	Total			
I. New England	12	2	14	67	21	5.6
II. New York-New Jersey	28	2	30	83	36	19.2
III. Middle Atlantic	7	2	9	245	4	6.7
IV. Southeast	11	1	12	736	2	5.0
V. Great Lakes	29	0	29	524	6	20.0
VI. South Central	4	2	6	502	1	1.9
VII. Central	7	0	7	411	2	2.9
VIII. Mountain	14	1	15	291	5	3.0
IX. West	26	6	32	88	36	20.7
X. Northwest	10	0	10	119	8	3.5
Total	148	16	164	3066	5	88.5

Note: Counties not in violation of primary CO standards were classified as "cannot be classified or better than national standards."

Source: Based on U.S. Environmental Protection Agency SAROAD data system and U.S. Bureau of the Census data.

traveled for their first 50 thousand miles of operation. According to the latest calculated Mobile Source Emission Factors, however, the deterioration factor for carbon monoxide emissions in these autos should deteriorate by approximately 2.0 grams per mile per year of vehicle operation.[77]

In the 1977 Council on Environmental Quality (CEQ) annual report, projections of future carbon monoxide ambient quality were developed, based on data in the CEQ's UPGRADE system.[78] This analysis (Table 4-23) suggests that primary ambient carbon monoxide standards can be met in all but seven urban areas by 1985, and that these remaining cities can be brought into compliance by 1990.

The CEQ assumptions can be contrasted with those underlying the SEAS scenarios. The CEQ analysis assumed that an 80 percent reduction in auto emissions from 1975 could be obtained in urban areas if the average emissions from the 1990 auto fleet were 15 grams per mile and if central city vehicle traffic were to increase at 1 percent per year. SEAS projections, based on similar emission factors, estimate a 70 percent decrease in total national auto emissions. CEQ also estimated a potential 50 percent reduction in truck-related emissions by 1990, based on the application of current controls and a 2 percent per year increase in truck vehicle miles traveled. SEAS projects only a 20-30 percent decrease in these emissions over time, because faster growth rates are assumed for the trucking industry. CEQ also noted other factors supporting substantial improvements in carbon monoxide ambient quality, including the continuing "suburbanization" of urban areas and the resulting decentralization of mobile source emissions. Overall, the SEAS emission trends would generate improvements in air quality somewhat more modest than those forecast by CEQ, even if full compliance with mobile source control standards could be attained.

The issue of actual mobile source control efficiencies has been receiving a great deal of attention at EPA in recent years. A 1977 EPA review of the mobile source emissions control program found that the vast majority of the 1972-1975 model year vehicles tested for emissions were substantially in violation of current carbon monoxide standards.[79] Actual emissions ranged from 150 to 225 percent of

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[77] U.S. Environmental Protection Agency, Office of Air and Waste Management, Mobile Source Emission Factors, December 1977.

[78] Council on Environmental Quality, Environmental Quality - 1977: The Eighth Annual Report, December 1977.

[79] Korb, B.R. et al., Review of EPA's Emission Control Program for Light Duty Vehicles, draft report, December 1977.

TABLE 4-23
TRENDS IN URBAN AMBIENT AIR QUALITY
1975, 1985, 1990

Urban Area[a]	Number of Days in Violation of Primary Carbon Monoxide Standards		
	1975	1985	1990
Albuquerque	118	17	1
Chicago	154	5	0
Denver	104	13	1
Fairbanks	84	3	0
Los Angeles	125	13	0
New York	234	11	0
Spokane	77	3	0

[a] All other urban areas assumed to be in full compliance by 1985.

Source: Council on Environmental Quality, Environmental Quality - 1977: The Eighth Annual Report, December 1977.

promulgated levels, primarily as a result of inadequate owner maintenance. Improvements in enforcement, particularly state implementation of mandatory emission inspection and maintenance programs, will be needed to reduce these disparities in future years.

Health Implications

If the enforcement problems can be solved, the declining carbon monoxide emission trends should produce some positive effects for human health in urban areas. It should be noted, however, that indoor levels of carbon monoxide are not controlled. Health consequences of indoor exposure may be significant, particularly where ventilation is inadequate.

The health effects associated with carbon monoxide emissions are fairly well understood. Contact with high daily concentrations of carbon monoxide frequently results in short-term problems like nausea, headaches, and dizziness. On a long-term basis, the primary risk of carbon monoxide exposure is to people with cardiovascular disease and has been noted for individuals with angina pectoris. About 4.2 million persons in the United States experience frequent attacks of chest pains, up to several times a day, from this condition. A CEQ health risk assessment of conditions in nine urban areas estimated that carbon monoxide emissions were responsible for 126,000 angina attacks in 1975, or 0.3 percent of the total attacks estimated for the metropolitan areas studied.[80] Both short- and long-term health problems can be expected to be substantially reduced as a result of the projected emissions reductions in urban locales.

4.8.7 Synergistic Effects of Air Pollutant Emissions

Many of the critical air pollution problems facing the nation result not from a particular pollutant, but from interaction between the various components of air pollutants (including their transformation into forms more harmful to human health). Three of these synergistic relationships are examined here: (a) the combined effects of high sulfur dioxide and particulate emissions; (b) the transformation of sulfur oxides and nitrogen oxides into acidic ions, and their subsequent deposition into watercourses through precipitation; and (c) the roles of nitrogen oxides and hydrocarbons in the formation of photochemical smog.

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[80] Jones, K.H., "Development of a Relative Exposure Factor for the CEQ Health Risk Model," Council on Environmental Quality, Washington, D.C., 1978.

Synergistic Effects of SO_x and Particulates

Aside from the potential direct health effects of suspended sulfate particles and gaseous sulfur dioxide, synergistic effects are theorized to occur when very fine particulates (less than 1 micron in diameter) adsorb sulfur dioxide and forms of sulfates, such as sulfuric acid (H_2SO_4). As discussed previously, fine particulates are a significant respiratory irritant in themselves, as are sulfur oxides (SO_x). When adsorbed onto the surfaces of fine particles, the effects of sulfur oxide compounds may be increased because these particles tend to remain in the respiratory system for long periods.[81] Studies have shown that this synergistic effect causes "increased death rates for persons over 50 years of age" when particulate concentrations are above 100 micrograms per cubic meter and sulfate levels result in a sulfate precipitation rate of above 30 milligrams per square centimeter area per month.[82,83]

This means that regions with both high sulfur oxides and high particulate concentrations, as in the Middle Atlantic and Great Lakes Regions (Federal Regions III and V), are more likely to experience greater adverse health effects from the combined effects of sulfur oxides and particulates.

Those counties that are concurrently in violation of sulfur dioxide and TSP standards are identified in Table 4-24. Since both particulate and sulfur oxide emissions are expected to decline in Federal Regions III and V, as well as in the Northeast (Federal Regions I and II) and Southeast (Federal Region IV), the potential negative effects on these localities may decline overall in spite of the increase in regional population. The South Central Region (Federal Region VI), however, is projected to have sharp increases in sulfur oxides and increases in particulates and may therefore experience much higher levels of air pollution-related respiratory disease.

Acid Precipitation

The mechanisms for acidic ion formation and the potential health and ecological effects of acid precipitation are described in Chapter 5 (Section 5.3) of this report. Areas in the United States where acidic rainfall has been recorded are identified in Figure 4-25.

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[81] American Chemical Society, Cleaning Our Environment, A Chemical Perspective, 2nd Ed., Washington, D.C., 1978.

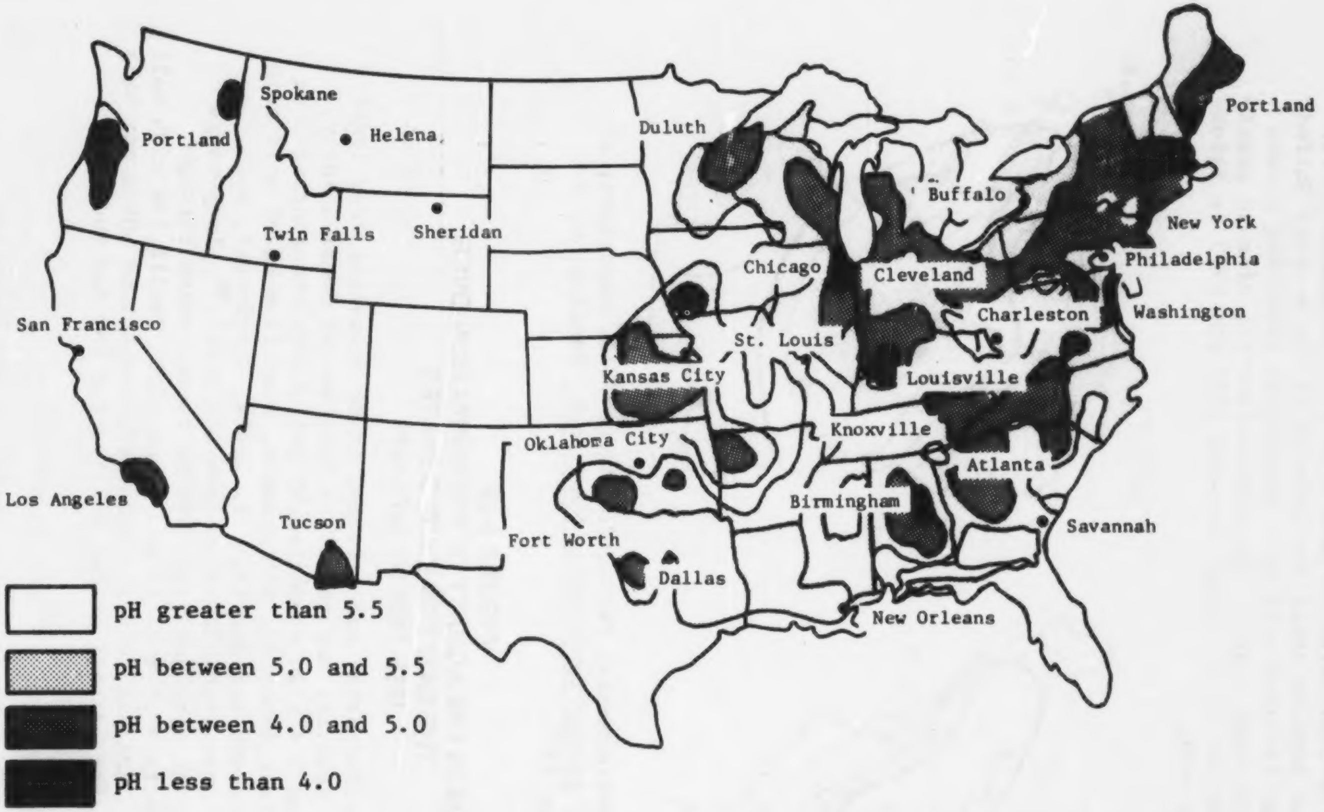
[82] As reported in Greenfield, Attaway and Tyler, Inc., A Review of the National Ambient Quality Standards for Sulfur Oxides and Particulate Matter, San Rafael, California, July 1975.

[83] mg/cm^2/month is the quantity that precipitates or settles into a square centimeter plate in 1 month's time.

TABLE 4-24
REGIONAL DISTRIBUTION OF COUNTIES WITH VIOLATIONS OF BOTH SULFUR DIOXIDE AND PARTICULATE STANDARDS
1975

Region		Number of Counties	Population Affected (Millions)
I	New England	0	--
II	New York-New Jersey	7	10.6
III	Middle Atlantic	6	4.1
IV	Southeast	4	2.0
V	Great Lakes	18	11.5
VI	South Central	0	--
VII	Central	1	1.1
VIII	Mountain	2	0.6
IX	West	4	3.7
X	Northwest	2	0.5
	Total	44	33.1

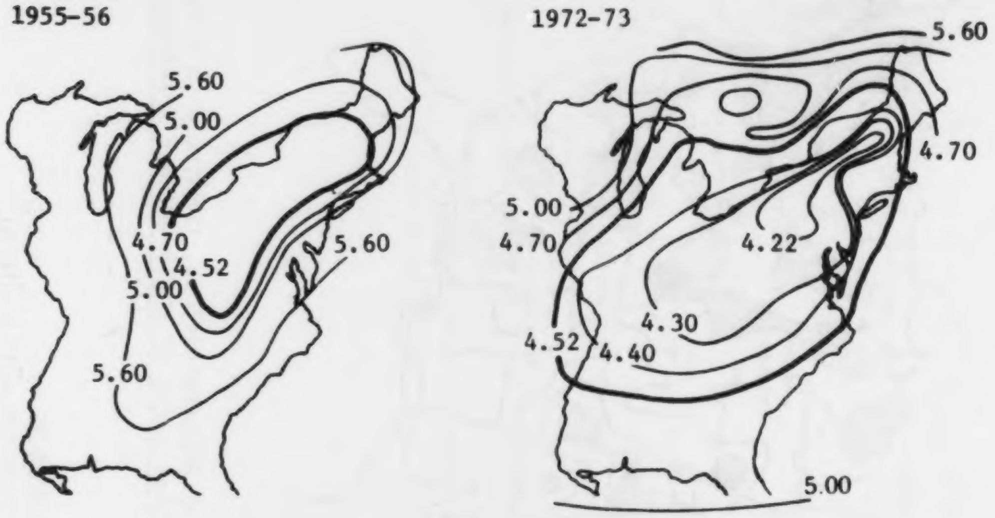
Source: Based on U.S. Environmental Protection Agency SAROAD data system and U.S. Bureau of the Census data.


Portland
Spokane
Helena
Portland
Twin Falls
Sheridan
San Francisco
Los Angeles
Tucson
Duluth
Chicago
Kansas City
St. Louis
Oklahoma City
Fort Worth
Dallas
Buffalo
Cleveland
Charleston
Louisville
Knoxville
Birmingham
Atlanta
New Orleans
Savannah
New York
Philadelphia
Washington
Portland
pH greater than 5.5
pH between 5.0 and 5.5
pH between 4.0 and 5.0
pH less than 4.0

Source: U.S. Congress, U.S. House of Representatives, Committee on Science and Technology, Environmental Challenges of the President's Energy Plan, October 1977.

FIGURE 4-25
REGIONAL DISTRIBUTION OF ACID RAINFALL

Normal rainfall is considered to have a pH of approximately 5.6. Most of the major problem areas are located in the eastern United States, with some isolated acid rain conditions occurring around urban areas on the West Coast. The intensification of acid precipitation problems in the Northeast between 1955 and 1973 is illustrated in Figure 4-26.



Source: U.S. Environmental Protection Agency/U.S. Department of Energy, Energy/Environment Fact Book, Washington, D.C., December 1977.

FIGURE 4-26
TRENDS IN THE ACIDITY OF PRECIPITATION OVER THE EASTERN UNITED STATES
1955-1956 TO 1972-1973

Although sulfur oxide and nitrogen oxide emissions from local fuel combustion activity may result in substantial local acidity, acidic conditions are also supported by pollutants transported long distances. At Lake Superior, for example, constituents of acid rain are said to represent fallout from St. Louis, Cincinnati, and Pittsburgh (all more than 500 miles from the lake).[84] Long-range transport of acidic ions has increased in recent years through expanded construction of smelter and power plant facilities with tall exhaust stacks. EPA has recently proposed regulations which may help to limit the number of tall stacks constructed for new sources.

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[84] Gannon, J., "Acid Rain Fallout: Pollution and Politics," National Parks and Conservation Magazine, October 1978, pp. 16-21.

In most regions, sulfur oxide is more important than nitrogen oxides as a contributor of acidic ions to precipitation. Studies by Likens[85] estimate that, in the northeast, sulfates represented about two thirds of the acid component, and nitrates, about one-third. However, Likens concluded that the relative contribution of nitrogen oxides to excess acidity had doubled in the decade between 1964 and 1974. Furthermore, a 1978 study of acid rainfall in Pasadena, California, indicates that nitric acid contributed almost three-fifths of total ions.[86]

Acid rains and snowfalls are likely to increase in frequency and intensity over the next 25 years, despite attempts to control the precursor pollutants, sulfur oxides and nitrogen oxides. Between 1975 and 2000, the SEAS model projects a 6 percent increase in sulfur oxide emissions and a 43 percent increase in nitrogen oxide emissions under conditions of high economic and energy growth. The negative impacts of these increases would be somewhat mitigated by the fact that the fastest growth in emissions would occur in the southwest and Rocky Mountain areas, neither of which has current acid rainfall problems. On the other hand, a larger portion of total emissions, particularly of nitrogen oxide, will be released from tall stacks and may be more susceptible to long-range transport and transformation into acidic forms.

Photochemical Oxidant Formation

The extent of the problem is illustrated by information on the counties in the United States that were in violation of the primary ambient air quality standard for oxidants in 1975 (Table 4-25).[87] Although oxidant problems were pervasive throughout the nation, they were particularly concentrated in the northeast (Federal Regions I, II, and III). Over three-fourths of the urban (SMSA) counties in the United States were not in compliance because of heavy concentrations of motor vehicle transportation in metropolitan areas.

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[85] Likens, G.E., "Acid Rain: A Serious Regional Environmental Problem," Science, Vol. 184, 1974, pp. 1176-1179.

[86] Liljestrand, H.M., and J.J. Morgan, "Chemical Composition of Acid Precipitation in Pasadena, California," Environmental Science and Technology, December 1978, pp. 1271-1273.

[87] It should be noted that the data presented here were assembled on the basis of differing definitions of the oxidant standard. The 1975 compliance information is based on oxidant standard of 0.1 ppm then in effect. The 1978 CEQ projections of ambient conditions use a proposed standard of 0.08 ppm of ozone (which was actually relaxed to 0.12 ppm of ozone in the new standard promulgated in 1979).

TABLE 4-25
REGIONAL DISTRIBUTION OF COUNTIES WITH VIOLATIONS OF EPA OXIDANT STANDARDS
1975

Region	Counties in Violation			Number of Counties in Region	Percent of Counties in Violation
	Urban	Rural	Total		
I. New England	17	48	65	67	97
II. New York-New Jersey	38	45	83	83	100
III. Middle Atlantic	46	116	162	245	66
IV. Southeast	38	26	64	736	9
V. Great Lakes	82	76	158	524	30
VI. South Central	23	15	38	502	8
VII. Central	17	1	18	411	4
VIII. Mountain	10	10	20	291	7
IX. West	21	15	36	88	41
X. Northwest	7	2	9	119	8
Total	299	354	653	3066	21

Note: Counties in violation of primary oxidant standards were classified as "cannot be classified or better than national standards." Less than 300 counties were being monitored for oxidants in 1975.

Source: Based on U.S. Environmental Protection Agency SAROAD data system.

The elimination of either precursor pollutant (nitrogen oxide or hydrocarbon) should logically reduce the formation of oxidants by limiting the availability of one of the essential components. Several studies have tried to determine the relative value of reducing concentrations of nitrogen oxide and hydrocarbons in inhibiting the photochemical process. In general, the results suggest that reducing either precursor would reduce the rate of oxidant formation. Current regulatory practices have attempted to control oxidants almost entirely by limiting hydrocarbon emission. Estimates of the regional air quality implications of compliance with existing hydrocarbon standards were prepared by the Council on Environmental Quality and are summarized in Table 4-26.

The scenario projections of emissions for the precursors of oxidant formation are discussed in Sections 4.4 and 4.5. Nitrogen oxide emissions are projected to increase to about 125-150 percent of the 1975 levels because of increased use of coal as a fuel and the lack of adequately demonstrated control technologies to place on these emissions. Hydrocarbon emissions, on the other hand, are projected to decrease significantly, due to the impact of currently mandated control measures imposed on automobiles, the major source of the hydrocarbon emissions.

The significance and impacts of these countervailing trend projections are difficult to assess for two main reasons:

1. A satisfactory general model of the atmospheric reactions involving nitrogen oxide and hydrocarbons has not yet been developed, so it is difficult to say what levels of oxidant production would result from the increase in nitrogen oxides and decrease of hydrocarbons.
2. Oxidant formation is further complicated by the "transport phenomenon," that is, the movement of air from one area to another. The transportation of either nitrogen oxide or hydrocarbons to another area where the other is present can cause the production of oxidants in that area. Studies in Los Angeles have indicated that a substantial portion of total oxidant formation is taking place downwind of the original discharge points.

TABLE 4-26
EXPECTED HYDROCARBON EMISSIONS REDUCTION AND AIR QUALITY IMPROVEMENTS
1975 and 1990

Area	Percent HC Reduction	Days Above Oxidant Standards 1975	Days Above Oxidant Standards 1990	Percent Reduction in Days
Baltimore	59	51	5	90
Boston	61	41	0	100
Chicago	48	33	2	94
Cincinnati	58	50	0	100
Denver	65	70	0	100
District of Columbia Metropolitan Area	64	61	<1	99
Houston	48	75	9	88
NY., N.J., Conn.	61	77	4	95
Philadelphia	58	102	9	91
St. Louis	53	54	2	97
San Francisco	53	84	3	96
California South Coast Basin				
Upland	59	247	40	84
Pasadena	59	195	25	87

Source: Council on Environmental Quality, Environmental Quality--1977: The Eighth Annual Report, Washington, D.C., December 1977, p. 183.

CHAPTER 5
GLOBAL ATMOSPHERIC POLLUTION

HIGHLIGHTS OF CHAPTER 5

- Carbon dioxide concentration, acid deposition, and stratospheric ozone depletion are major issues in global atmospheric pollution.
- The important pollutants fall into three categories: those stable in the troposphere and stratosphere, those unstable in the troposphere, and those stable in the troposphere but unstable in the stratosphere.
- The emitted pollutants in each case exhibit sufficiently long lifetimes in the atmosphere to be transported long distances and thereby have widespread influence.
- The global effects of atmospheric pollution have not yet been quantitatively determined, but this problem merits worldwide concern.

5.1 INTRODUCTION

The topics in this chapter--carbon dioxide concentration, acid deposition, and stratospheric ozone depletion--are major issues in atmospheric pollution. Their impacts have growing global implications.

In each case, emitted pollutants exhibit sufficiently long lifetimes in the atmosphere to be transported long distances and thereby have widespread influence. Carbon dioxide is, for all practical purposes, uniformly distributed in the atmosphere even though its sources are concentrated in the Northern Hemisphere. Acid precipitation results mainly from nitrogen and sulfur compounds, which are transported regionally before becoming the sulfates and nitrates that create the acidic precipitation. In ozone depletion, the long-range transport of ozone-depleting compounds and elements is vertical, resulting in increased concentrations of these materials in the stratosphere, where they accelerate the natural destruction of ozone.

The effects of these processes on people and the environment have not yet been quantitatively determined. So far as we know now, only acid deposition exhibits short-term effects. The atmospheric concentration of carbon dioxide is known to have increased over the past 100 years, yet the possible climatic impacts resulting from an altered earth radiation budget have not been observed, perhaps because the magnitude of natural climatic variation is sufficient to dwarf human impact at this time. The ozone depletion predicted to result from release of chlorofluorocarbon gases, or from aircraft flight in the stratosphere, has yet to be detected; again the reason is that large natural variation may mask the probable effect.

Each of these problems merits worldwide concern, not only because the sources of pollutants are widely distributed but also because the adverse effects would be suffered globally. Further, at least for CO_2 and ozone depletion, even stringent control efforts that would completely eliminate the causes would not result in immediate cessation of the effects. The time scale of chemical reactions, transport and climate dynamics suggest, in both of these cases, that decades might pass before maximum impact on the atmosphere would occur.

5.2 CARBON DIOXIDE

HIGHLIGHTS OF SECTION 5.2

- Carbon dioxide is stable in the troposphere and stratosphere and is expected to influence global climate as its atmospheric concentration rises, predominantly as a result of fossil fuel combustion, deforestation, and changing land use patterns.
- Controlling fossil fuel combustion emissions or reversing deforestation appears to be difficult technically, economically, and socially.
- Carbon dioxide control strategies may be classified according to choice of fuels or energy technology, CO_2 capture, CO_2 storage, or CO_2 conversion.
- Regional shifts in temperature and precipitation could have profound impacts on agriculture, regional hydrology and energy use, resulting in profound sociopolitical consequences.

5.2.1 Introduction

Problem Identification and Regulatory Background

According to West Germany's Chancellor Helmut Schmidt,[1]

> Forseeably, we will within the next two decades get into a worldwide debate about the irrevocable consequences of burning hydrocarbons--whether oil or coal or lignite or wood or natural gas--because the carbon dioxide fallout, as science more or less equivocally tells us, results in a heating up of the globe as a whole.

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[1] As reported in *Time* 113(24), June 11, 1979, p. 39.

Many scientists believe that the burning of fossil fuels is the largest contributor to rising atmospheric CO_2 levels.[2] Others suggest that deforestation may also play a prominent role.[3]

Increased atmospheric CO_2 acts as a one-way filter for the sun's energy, conceivably warming the earth enough to cause significant worldwide climatic and environmental changes. In this so-called "greenhouse effect," atmospheric CO_2 is transparent to visible light but absorbs infrared radiation (IR) emitted by the earth's surface to space. As atmospheric CO_2 levels rise, less IR heat escapes freely to space, and a portion of the now absorbed heat is re-radiated back to earth.

The projected trends discussed later indicate that only with optimistic assumptions concerning the mechanisms of the global carbon cycle and with low growth rates in use of fossil fuel for energy will the CO_2-induced temperature increase be held below an average of 2°C during the next century. Finally, uncertainty over future fossil fuel use growth rates, associated temperature effects, and the existence of compounding factors (such as particulate emissions that accompany fossil fuel burning and may offset, somewhat, CO_2-induced global warming) will contribute to the CO_2 problem as a major environmental concern through the 1980s.

No existing U.S. environmental regulations specifically address control of CO_2 emissions. However, if the CO_2 problem were to assume more importance, two sections of the Clean Air Act (CAA) Amendments of 1977 could be brought to bear. The first, Section 122, authorizes the Administrator of the Environmental Protection Agency to review any unregulated pollutant and, if deemed appropriate, to classify it as a criteria air pollutant under Section 108 to "...protect public health and welfare." Section 157, among others in Part B of the CAA Amendments of 1977, also enables EPA's Administrator to promulgate regulations for control (taking into account the feasibility and costs of control) of "...any substance, practice, process or activity [which] may reasonably be anticipated to affect the stratosphere, especially ozone in the stratosphere, and [for which] such effect may reasonably be anticipated to endanger public health or welfare." Nevertheless, if CO_2 regulation becomes necessary, the scope and magnitude of such regulation may likely require specific enabling legislation.

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[2] Baes, C.E., Jr., H.E. Goeller, J.S. Olson, and R.M. Rotty, "Carbon Dioxide and Climate: The Uncontrolled Experiment," American Scientist, Vol. 65, 1977, p. 310. Also see Bolin, B., "The General Circulation of the Atmosphere and the Distribution of Climatic Zones," Annual Review of Energy, Vol. 2, 1977, pp. 204-218. Also, Keeling, C.D. and R.B. Bacastow, "Impact of Industrial Gases on Climate," in Studies in Geophysics: Energy and Climate, National Academy of Sciences, Washington, D.C., 1977.

[3] Woodwell, G.M., R.H. Whittaker, W.A. Rivers, G.E. Likens, C.C. Delwiche, and D.B. Botkin, "The Biota and the World Carbon Budget," Science, Vol. 199, 1978, pp. 141-146. Also see Keeling, C.D., R.B. Bacastow, A.E. Bainbridge, C.A. Ekdahl, P.R. Guenther, L.S. Waterman, and J.F.S. Chin, "Atmospheric Carbon Dioxide Variations at the South Pole," Tellus, Vol. 28, 1976, p. 538.

In the United States, CO_2 research is the responsibility of the National Climate Program Office in the National Oceanic and Atmospheric Administration. Under the terms of the National Climate Program Plan, the Department of Energy has assumed research responsibility for CO_2 effects on the environment and society.

International Cooperation and Regulation

Section 156 of the CAA Amendments of 1977 empowers the President, through the Secretary of State, "...to enter into international agreements to foster cooperative research which complements studies and research authorized by this part [B], and to develop standards and regulations which protect the stratosphere." No such formal cooperation has yet been established concerning possible CO_2 pollution. However, international cooperation exists between the U.S. Climate Program and the National Academy of Sciences (Climate Research Board) through the World Meterological Organization. The "Earthwatch" program of the United Nations Environmental Program (UNEP), the International Institute for Applied System Analysis (IIASA), and the International Energy Agency (IEA) of the Organization for Economic Cooperation and Development (OECD) have been following and studying trends of increasing CO_2 levels in the atmosphere. These organizations' efforts have been supplemented by numerous international symposia on global carbon dioxide buildup over the past few years. Many of these meetings were sponsored by U.S. organizations.

Relevant Scenario Assumptions

To assess trends over the next 50 years in global carbon dioxide buildup in the atmosphere, two non-SEAS fossil fuel use scenarios have been devised. To establish an upper bound, global fossil fuel use to the year 2030 was assumed to follow current fossil energy use trends (average 4.3 percent increase per annum);[4] energy supply would grow somewhat slower in the United States, reaching 71 quads[5] total (20 quads coal) by 1985; 107 quads total (39 quads coal) by 2000; and only 144 quads total (129 quads coal) by 2030. To represent much lower growth in fossil energy use, another scenario was devised which assumes that global fossil fuel energy use would grow at 2 percent per year,[6] with the U.S. growth rates the same as those for the high growth case for 1985, slowing to 1.0 percent annually in 2000 (87 quads total, 30 quads coal) and to negative 0.8 percent per annum in 2030 (45 quads total, 25 quads coal).[7]

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[4] Baes, C.E., Jr., H.E. Goeller, J.S. Olson, R.M. Rotty, "Carbon Dioxide and Climate: The Uncontrolled Experiment," *American Scientist*, Vol. 65, 1977, p. 310.

Each of these two scenarios was analyzed in the context of each of two sets of scientific assumptions concerning mechanisms of the global carbon cycle. The first, or optimistic assumptions, are that 40 percent of CO_2 released by fossil fuel combustion remains in the atmosphere; 2 gigatons (GT)[8] of carbon per year are subtracted from the atmosphere due to terrestrial uptake; and the lower limit of possible CO_2-induced average temperature rise prevails. The second, or pessimistic assumptions, are that 60 percent of fossil fuel CO_2 released remains in the atmosphere; 1.2 GT of carbon per year (net) is added to the atmosphere because of deforestation; and the upper limit of possible CO_2-induced average temperature rise prevails. Thus, four resulting combinations of energy growth rates and scientific assumptions concerning CO_2 effects were analyzed. Note that these scenarios do not correspond to the SEAS High and Low Growth cases, which extend only to 2000. In general, the SEAS scenarios assume much greater total energy supply by 2000 (124 quads versus 107 quads in the high growth cases, respectively) but agree closely on coal supply in 2000. (See Table B-5, Appendix B, for SEAS scenario assumptions.)

Data Sources and Quality

Uncertainty characterizes present scientific understanding of the global carbon cycle and possible temperature changes from increased atmospheric CO_2. The major question concerns our lack of understanding of the ultimate fate of the approximately 40 percent of the CO_2 that does not remain in the atmosphere. In an attempt to reduce this uncertainty, research efforts are directed at identifying the role of the oceans as a long term sink, and the role of plants in absorbing or adding CO_2 to observed atmospheric levels. Recent evidence suggests that deforestation over the past 100 years has added to observed atmospheric CO_2 levels.[9]

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[5] One quad = 1 quadrillion Btu; 1 quad is the energy equivalent of more than 170 million barrels of crude oil.

[6] Baes, C.E., Jr., H.E. Goeller, J.S. Olson, R.M. Rotty, "Carbon Dioxide and Climate: The Uncontrolled Experiment," American Scientist, Vol. 65, 1977, p. 319.

[7] Ibid. Also, Battelle Columbus Laboratories and University of Michigan, First Year Report for Coal Technology Assessment Program, preliminary draft, prepared for U.S. Environmental Protection Agency, Contract #68-02-2622, N.D.

[8] One gigaton = 10^9 metric tons = 10^{15}g.

Manabe and Wetherald's[10] general circulation model is frequently used for predicting average global temperature rise for a given increase of CO_2 alone. Yet simple assumptions in that model and compounding factors complicate the relationship between increases in atmospheric CO_2 and temperature change. To account for possible counteracting mechanisms, the temperature ranges presented here have been biased on the optimistic (or low) side, as displayed in Table 5-1.

TABLE 5-1
RANGE OF CO_2-INDUCED TEMPERATURE RISE
(in °C)

	Low Latitude (0°-5°)		Average		High Latitude (80°-90°)	
Atmospheric CO_2 Compared to Preindustrial Levels	O[a]	P[a]	O	P	O	P
2x	0.8	2.4	1.5	2.9	3.6	11
4x	1.9	4.8	2.9	5.8	7.5	18
6x	2.8	6.0	4.1	7.5	9.0	20

[a] O = optimistic; P = pessimistic.

Source: Adapted from Markley, O.W., A.L. Webre, R.C. Carlson, and B.R. Holt, Socio-political Impacts of Carbon Dioxide Buildup in the Atmosphere Due to Fossil Fuel Combustion, prepared for U.S. Energy Research and Development Administration, 1977, p. 35. Table revised by R. Wetherald, R. Ramanthan, W.W. Kellogg, and J.M. Mitchell, Jr. Further revised by D.O. Gates, Professor of Botany and Director of Biological Field Station, University of Michigan, 1978.

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[9] Stuiver, M., "Atmospheric Carbon Dioxide and Carbon Reservoir Changes," Science, Vol. 199, 1978, pp. 253-258. Also, Wilson, A.T., "Pioneer Agriculture Explosion and CO_2 Levels in the Atmosphere," Nature, Vol. 273, 1978, pp. 40-41.

[10] Manabe, S. and R.T. Wetherald, "The Effects of Doubling the CO_2 Concentration on the Climate of a General Circulation Model," Journal of Atmospheric Science, Vol. 32, 1975, pp. 3-15.

Future energy growth is conjectural as well. This plenitude of uncertain information, hence, offers only upper and lower bounds for future CO_2-induced effects. Current research efforts are aimed at reducing these uncertainties.

Major sources for information on carbon dioxide in the atmosphere are referenced throughout this section. Of special value are a recent symposium report, Carbon Dioxide, Climate, and Society;[11] a National Academy of Sciences report, Studies in Geophysics: Energy and Climate;[12] and articles over the past few years in the journal Science.

5.2.2 Control Options

If CO_2 proves to be a pollutant of concern, control may be desirable. Controversy exists over whether present fossil fuel combustion or deforestation is contributing most to observed atmospheric CO_2 increases; however, projected annual growth rates in fossil fuel use point to the combustion of hydrocarbons as the most important area for future control. At any rate, controlling fossil fuel emissions or reversing deforestation might be exceptionally difficult technically, economically, and socially. It might be more feasible (though still unlikely) to curtail fossil fuel use and to clear less forest than to apply control technology.

A marked difference between CO_2 and other pollutants is the staggering amount of CO_2 generated, typically about 20 percent by weight of fuel gas from coal-fired power plants. This strongly affects technological control efforts. Carbon dioxide control strategies have only been explored in concept and may be classified according to choice of fuels or energy technology, CO_2 capture, CO_2 storage, or CO_2 conversion.

Choice of Fuels or Energy Technology

The amount of CO_2 formed during combustion is directly related to the carbon content of the fuel. Methane combustion emits about half as much CO_2 as coal in producing the same amount of end-use energy, as is shown in Table 5-2. Gasoline is intermediate. Considerable differences also exist in the amount of CO_2 emissions among different technologies at a given level of end-use energy. When systems extending from extraction to end use and their associated efficiencies are compared, furnace use is preferable to electric heating (see Table 5-3). Comparison of systems 6 and 8 in Table 5-3 shows that coal liquefaction for furnace use to provide space heating releases about half as much CO_2 as does coal liquefaction to generate electricity for space heating. In this comparison, both energy systems (6 and 8) are directed to the same end use, and no control technology is applied.

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[11] Williams, J., ed., Carbon Dioxide, Climate, and Society, Pergamon Press, Oxford, 1978.

[12] Geophysics Study Committee, National Research Council, Studies in Geophysics: Energy and Climate, National Academy of Sciences, Washington, D.C., 1977.

TABLE 5-2
CO_2 EMISSIONS FROM VARIOUS FOSSIL FUELS

Fuel Type	CO_2 Emitted (in lb/10^6 Btu)
Gas	
Methane	115
Propane	139
Butane	143
Liquid	
Gasoline	161
Diesel	167
No. 6	170
Coal	
Lignite	215
Sub-bituminous	215
Bituminous	212

Source: Adapted from American Gas Association, "Carbon Dioxide Emissions from Fossil Fuel Combustion and from Coal Gasification," Energy Analysis, Arlington, Virginia, 1977, p. 5.

In electricity generation, fluidized bed combustion, low-sulfur coal, physically cleaned coal, and conventional boilers with limestone scrubbing are all roughly equivalent in terms of CO_2 released, producing about 300 million metric tons of CO_2 per quad.

Synthetic fuels for electricity generation have CO_2 emissions about 30 percent higher than CO_2 emissions from direct coal combustion. Moreover, synfuels for furnace use to provide space heat release less CO_2 than does direct coal combustion for electric space heat (see systems 1 through 4 versus systems 7 and 8 in Table 5-3). A recent report to the Council on Environmental Quality (CEQ) also addresses CO_2 emissions from synthetic fuels. That report indicates that synfuels for electricity generation emit slightly more

TABLE 5-3
COMPARISON OF TECHNOLOGY SYSTEMS PRODUCING 1 QUAD PER YEAR OF SPACE HEATING

Systems[a,b]	Efficiencies[c]	Coal Consumed (10^{13}g/year)	CO2 Emitted[d] (10^{13}g/year)
Without CO_2 Control			
Electricity Generation			
Direct			
1. Low sulfur coal (LSC) boiler	0.37	11	28
2. Physical coal cleaning (PCC) with boiler	0.9 (cleaning) 0.37 (boiler)	13	31
3. Fluidized bed Combustion (FBC) boiler	0.36	12	28
4. Boiler with limestone scrubber	0.35	12	29
Synfuels			
5. Low Btu gasification with combined cycle	0.70 (gasification) 0.40 (combined cycle)	15	36
6. Liquefaction with boiler	0.625 (liquefaction) 0.37 (boiler)	18	44
Furnace Use			
7. High Btu gasification	0.65 (gasification) 0.97 (pipeline) 0.64 (furnace)	9	22
8. Liquefaction (assuming short haul in truck)	0.625 (liquefaction) 1.0 (transportation) 0.60 (furnace)	10	24
With CO_2 Control			
1. Low-sulfur coal boiler for electricity	0.27 (control point)	16	1[e]
7. High-Btu gasification for furnace use	0.62 (gasification - control point) 0.97 (pipeline) 0.64 (furnace)	9	18

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[a] Systems 1-6 assume electrical transmission efficiency at 0.912 and application efficiency (not heat pump) of 0.98.

[b] Bituminous coal feed assumed.

[c] Efficiency loss assumptions for CO_2 disposal have been included for the "with CO_2 controlled" systems.

[d] More CO_2 (dryweight, etc.) is produced than coal feed. Increase reflects the higher molecular weight of CO_2 over carbon, the carbon content of the coal, and the high percentage of reacted carbon when coal is combusted.

[e] Theoretically 100 percent control is possible; however, this figure represents optimistic system reliability. All figures have been rounded.

Source: Personal communication, E. Hall, Battelle Columbus Laboratory, 1978.

than twice the amount of CO_2 emitted by natural gas to produce the same end-use energy.[13]

CO_2 Capture

Costs, efficiency penalties, and resistance to its application may severely hamper, if not preclude, development of CO_2 control technology. The most likely control points for capturing CO_2 would be the stacks of fossil fuel and industrial plants, because of the relatively high concentration of CO_2 in the stacks. The process most likely to be used for CO_2 capture appears to be aqueous potassium carbonate scrubbing. However, complete scrubbing could lower ideal power plant efficiency from 37 percent to 30 percent (apart from energy penalties for disposal) and double the capital cost for a large power plant.[14]

Should atmospheric CO_2-induced warming effects arise, centralized conversion facilities would be the most amenable to control. A comparison of systems 1 and 7 in Table 5-3, with and without control technology, illustrates this point. Without control technology, system 7 is more efficient and therefore emits less CO_2 than system 1. With control technology, however, system 1 emits less CO_2 because of its amenability to control. This comparison takes into account the reduction of efficiency resulting from the application of control technology, indicated by the increased coal input required to deliver the same end-use energy.

CO_2 Storage

If vast amounts of CO_2 need to be stored anywhere, the deep ocean appears to be the most practical place. The ocean, besides its enormous capacity, already provides a natural permanent sink for CO_2. The long-term impacts of infusing CO_2 into the oceans, however, are unknown.

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[13] Woodwell, G.M., G.J. MacDonald, R. Revelle, and C.D. Keeling, "The Carbon Dioxide Problem: Implications for Policy in the Management of Energy and Other Resources," report to the Council on Environmental Quality, July 1979.

[14] Albanese, A., and M. Steinberg, Environmental Control Technology for Atmospheric Carbon Dioxide, BNL-50877, Brookhaven National Laboratory, Upton, New York, 1978, p. 7. Also, Marchetti, C., "Geo-Engineering and the CO_2 Problem," Climate Change, Vol. 1, 1977, p. 61. Also, Mudacchi, C., P. Aremenante, and V. Cena, in J. Williams, ed., Carbon Dioxide, Climate, and Society, Pergamon Press, Oxford, 1978, p. 289. Also, Steinberg, M., A.S. Albanese, and V. Dang, "Environmental Control Technology for Carbon Dioxide," presented at the 71st American Institute of Chemical Engineers (AICHE) Annual Meeting, Miami, Florida, 1978, p. 29.

Disposal of captured CO_2 would require additional energy. Up to 10 percent of the output from a power plant might be required to pump CO_2 captured from the flue gas to the ocean bottom,[15] further lowering ideal power plant efficiency to about 27 percent. Thus, this strategy would only be practical for power plants near the seacoast.

CO_2 Conversion

Reforestation, general fertilization of existing forests, and flue gas CO_2 conversion using bacterial action or greenhouse environments are possible additional control strategies. Application of such controls would be limited by requirements for nutrients, available land, and water. These methods would be very expensive.

5.2.3 Trends

To assess the need for CO_2 control, apart from efficacy of control, more definitive information is needed in four areas: the mechanisms of the global carbon cycle, present and future CO_2 emissions, the impact of such emissions on ambient atmospheric CO_2 levels, and the influence of ambient CO_2 levels and other factors on trends in worldwide temperature and other climate changes.

Global Carbon Cycle

Carbon is cycled among three main reservoirs or repositories: terrestrial, atmospheric, and oceanic. Whether the net flux (or transfer of carbon) from each of these reservoirs is positive or negative determines whether each of the reservoirs is considered as a source or a sink for CO_2. An additional reservoir, that of carbon stored in fossil fuels and carbonates, can be treated as an exogenous variable. Human use of such stored carbon invariably results in CO_2 emissions. Figure 5-1 is a simplified representation of the global carbon cycle with three additional subdivisions: the ocean pool divided into a surface layer, a thermocline (mixed), and a deep (unmixed) layer; the land reservoir, split into biota and humus; and the terrestrial-atmospheric fluxes arising from natural causes and human activities.

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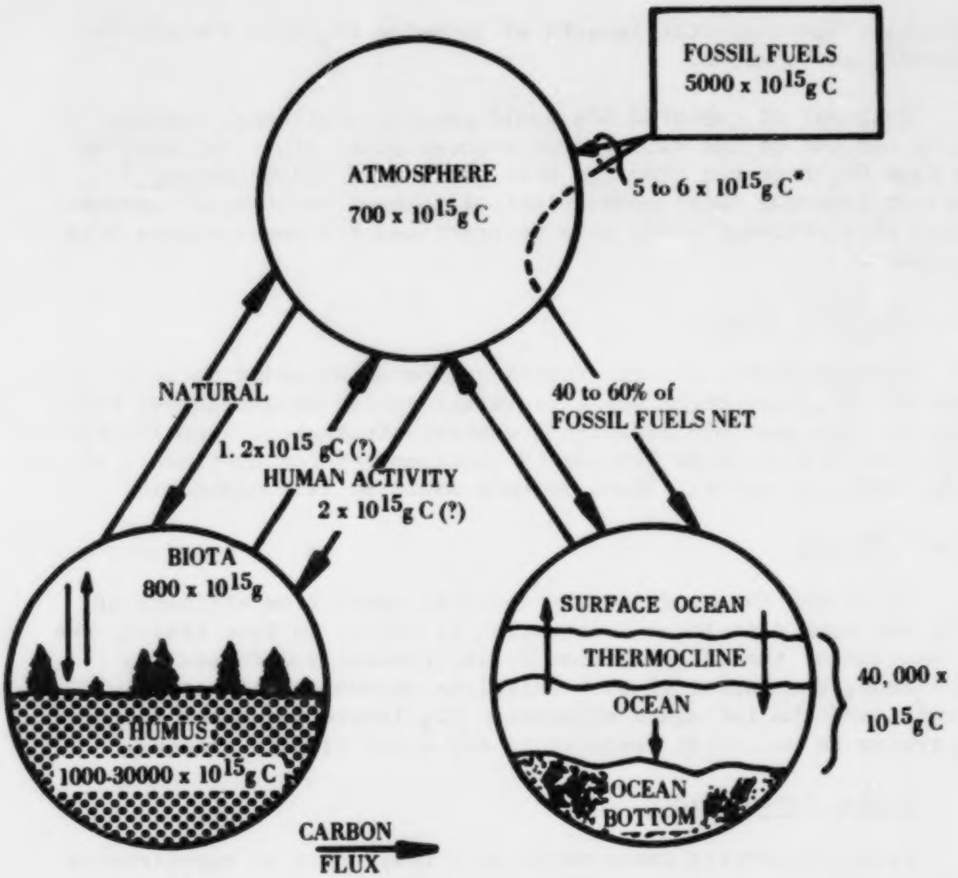
[15] Albanese, A., Follow-up Report to EPA's Coal Technology Assessment CO_2 Forum, University of Michigan, December 1978.


FOSSIL FUELS
5000 x 10^{15}g C
ATMOSPHERE
700 x 10^{15}g C
5 to 6 x 10^{15}g C*
NATURAL
1. 2x10^{15} gC (?)
HUMAN ACTIVITY
2 x 10^{15}g C (?)
40 to 60% of
FOSSIL FUELS NET
BIOTA
800 x 10^{15}g
HUMUS
1000-30000 x 10^{15}g C
SURFACE OCEAN
THERMOCLINE
OCEAN
OCEAN
BOTTOM
40, 000 x
10^{15}g C
CARBON
FLUX

* The fossil fuel growth Scenarios project this to rise to 46 x 10^{15} g C in the year 2030 for the high growth case, or 12 x 10^{15} gC per year in 2030 for the low growth case.

Source: Carbon reservoir estimates are from Woodwell, G.W. et al., The Carbon Dioxide Problem: Implications for Policy in the Management of Energy and Other Resources, A Report to The Council on Environmental Quality, July 1979. For estimates of flux, see text.

FIGURE 5-1
SIMPLIFIED REPRESENTATION OF THE WORLD CARBON CYCLE

Emission Trends

Natural Fluxes. Natural sources of CO_2 emissions to the atmosphere include plant respiration, humus decay, volcanic emissions, weathering, and forest fires. Natural sinks for atmospheric CO_2 include plant growth, sedimentation processes, land carbonates, peat soils, and the oceans (subdivided into the surface, mixed, and deep ocean, and including sedimentation and marine debris deposition processes). By far the largest reservoir for carbon is the ocean, followed by the terrestrial reservoir and, distantly, the atmospheric reservoir (see Figure 5-1).

Estimates of the amount of flux between these reservoirs are usually extrapolated from relatively small and heterogeneous samples, and vary widely. For example, the size of the terrestrial carbon reservoir in humus alone has been estimated to be 55 GT carbon,[16] 700 GT,[17] 1,450 GT,[18] 3,000 GT,[19] to as much as 9,000 GT.[20] The terrestrial reservoir is less well understood than the oceanic or atmospheric reservoirs. This disparity makes the estimate of fluxes between reservoirs highly uncertain. Those fluxes (except that arising from fossil fuel combustion) shown in Figure 5-1 should thus be viewed cautiously.

Fluxes Due to Human Activity. It is difficult, if not impossible, to separate natural fluxes from those due to human activity. Human activity creates CO_2 sources through industrial activity, such as the making of cement or fertilizers, the use of fossil fuels for energy, and deforestation. Sinks for CO_2 may result from reforestation, transforming wood products into structures; and, perhaps secondarily, enhanced plant photosynthesis from the use of fertilizers or, over the long term, elevated CO_2 levels.

Burning fossil fuels releases CO_2 from organic carbon stored over hundreds of millions of years. Recent estimates suggest that roughly 140 GT of carbon have been emitted to the atmosphere from fossil-fuel burning since the beginning of the Industrial Revolution.[21] Between 40 GT and 120 GT of carbon have been emitted as a result of deforestation and agriculture over this period,[22] though the rate may have slowed in recent decades. Of this amount, perhaps 70 GT of carbon have remained in the atmosphere. The uncertainty arises because of varying estimates of preindustrial CO_2 levels and CO_2 emission rates over the past 100 years. The most important point, however, is that human activity, especially the use of fossil fuels, is increasingly adding CO_2 to an already imbalanced global carbon cycle.

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[16] Whittaker, R.H., Communities and Ecosystems, 2nd ed., MacMillan Company, New York, 1975.

[17] Bolin, B., "The Carbon Cycle," Scientific American, Vol. 223, September 1970, p. 124.

[18] Schlesinger, W.H., "Carbon Balance in Terrestrial Detritus," Annual Review of Ecology Systematics, Vol. 8, No. 73, 1977. This article is a general review of the carbon balance in terrestrial detritus.

[19] Bohn, H.L., "Estimate of Organic Carbon in World Soils," Soil Science Society of America, Journal, Vol. 40, 1976, pp. 468-470.

[20] Reiners, W.A., "Terrestrial Detritus and Carbon Cycle," Brookhaven Symposium - Biology, Vol. 24, 1973, pp. 303-327.

Ambient CO_2 Trends

Historical Trends. Figure 5-2 shows historic trends in atmospheric CO_2 increase over the past 100 years or so. Note that detailed monitoring of atmospheric CO_2 levels was not begun until 1958[23] on Mauna Loa in Hawaii, and now there are numerous such monitoring stations, worldwide. Preindustrial (c. 1860) CO_2 levels are commonly thought to have been about 290 ppm,[24] though recent reports suggest levels as low as 268 to 270 ppm.[25] From 1958 to 1968, observed annual atmospheric CO_2 increase averaged 0.75 ppm and had exceeded 1 ppm by 1974.[26] The present level of CO_2 in the atmosphere is 330 to 340 ppm, with the variation ascribed to "pulses" in CO_2 uptake (Figure 5-2) corresponding to major plant growing seasons.[27]

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[21] Bolin, B., in J. Williams, ed. Carbon Dioxide, Climate, and Society, Pergamon Press, Oxford, 1978.

[22] Ibid.

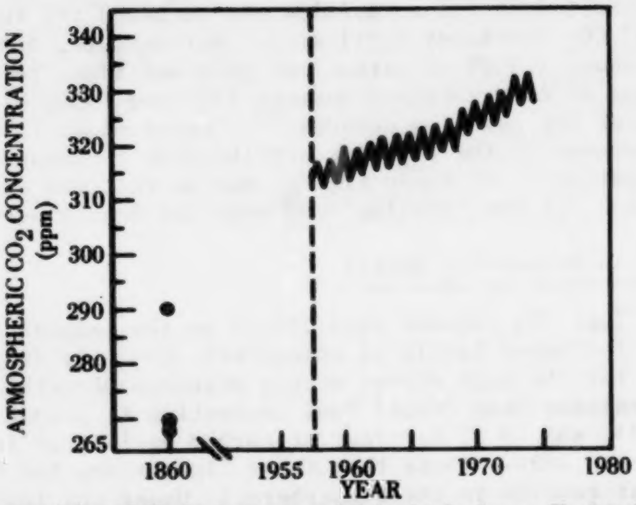
[23] Keeling, C.D., R.B. Bacastow, A.E. Bainbridge, C.A. Ekdahl, P.R. Guenther, L.S. Waterman, J.F.S. Chin, "Atmospheric Carbon Dioxide Variations at the South Pole," Tellus, Vol. 28, 1976, p. 538.

[24] Siegenthaler, U. and H. Oeschger, "Predicting Future Atmospheric Carbon Dioxide Levels," Science, Vol. 199, January 27, 1978, p. 388. Also, Bray, J.R., "An Analysis of the Possible Recent Change in Atmospheric Carbon Dioxide Concentration," Tellus, Vol. 11, 1959, p. 220.

[25] Keeling, C.D., R.B. Bacastow, A.E. Bainbridge, C.A. Ekdahl, P.R. Guenther, L.S. Waterman, and J.F.S. Chin, "Atmospheric Carbon Dioxide Variations at the South Pole," Tellus, Vol. 28, 1976, p. 538.

[26] Ibid.

[27] Oeschger, H. and U. Siegenthaler, in J. Williams, ed., Carbon Dioxide, Climate, and Society, Pergamon Press, Oxford, 1978, pp. 53-54. The authors cite vegetational cycles as the probable major cause in observed annual atmospheric CO_2 oscillations, hemispherical cycles due to temperature-induced variations in ocean and sea ice, CO_2 partial pressure; they also note season cycles in winter heating.



Note: The dots represent pre-industrial CO_2 level estimates and their related reference. The dotted line indicates when the first continous monitoring of CO_2 levels began. The oscillating line is from the Mauna Loa observatory.

Source: Keeling, C.D., R.B. Bacastow, A.E. Bainbridge, C.A. Ekdahl, P.R. Guentner, L.S. Waterman, J.F.S. Chin, "Atmospheric Carbon Dioxide Variations at the South Pole," Tellus, Vol. 28, 1976, p. 538. Used with permission.

FIGURE 5-2
HISTORICAL TRENDS IN ATMOSPHERIC CARBON DIOXIDE CONCENTRATIONS

Recent energy growth rates have averaged 4.3 percent annually.[28] The current annual rate of fossil fuel CO_2 emissions is approximately 5-6 GT of carbon, or about 2 ppm of equivalent atmospheric concentration.[29] Thus, roughly 50 percent of known fossil fuel release of CO_2 is not accounted for in observed atmospheric levels. It is chiefly this question of the "missing" CO_2 that has led to the necessity of considering the two widely differing pessimistic and optimistic assumptions for the mechanism of the global carbon cycle noted previously. If CO_2 emissions due to deforestation and other industrial activities are factored in, the percentage of "missing" CO_2 increases still more. For example, Stuiver maintains that about 1.2 GT of carbon per year was added to the atmosphere because of deforestation between 1850 and 1950, with smaller increases over the past few decades.[30] Cement production may add another 2 percent to the CO_2 flux attributable to human activity. The real implication of these figures may be that the ocean is a more effective sink for the "missing" CO_2 than had been thought.

Trends in Future CO_2 Levels

Fossil fuel CO_2 release will likely be the largest future contributor to increased levels of atmospheric CO_2. As displayed in Figure 5-3, for the high energy supply scenario described in Section 5.2.1, CO_2 release from fossil fuel combustion is projected to reach 8.5, 14, and 46 GT per year of carbon equivalent in the years 1985, 2000, and 2030. (Note that these figures are for CO_2 emitted, not what remains in the atmosphere.) Under the low energy use assumption, these figures are 6, 8, and 12 GT of carbon, respectively.

Two trends are common to both scenarios. First, over the next 50 years, the U.S. fossil fuel contribution to world CO_2 release is projected to decrease from the present 28 percent to only 8 percent of total CO_2 release by the year 2030. This changing percentage in contribution reflects a slowdown in U.S. energy growth rates in comparison to those of the rest of the world, especially in developing countries. Second, the contribution from coal increases to 40 to 60 percent of total fossil fuel CO_2 release by the year 2030.

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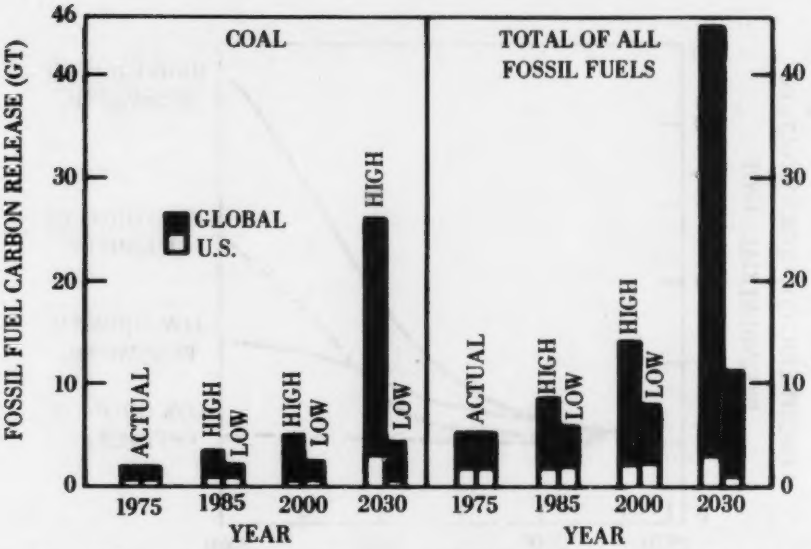
[28] Baes, C.E., Jr., H.E. Goeller, J.S. Olson, and R.M. Rotty, "Carbon Dioxide and Climate: The Uncontrolled Experiment," American Scientist, Vol. 65, 1977, p. 310.

[29] Keeling, C.D., R.B. Bacastow, A.E. Bainbridge, C. A. Ekdahl, P.R. Guenther, L.S. Waterman, J.F.S. Chin, "Atmospheric Carbon Dioxide Variations at the South Pole," Tellus, Vol. 28, 1976, p. 538.

[30] Ibid.



Source: Chen, K., R.C. Winter, and M.K. Bergman, "CO_2 from Fossil Fuels: Adapting to Uncertainty," submitted for publication. Used with permission.

FIGURE 5-3
U.S. AND GLOBAL CONTRIBUTIONS TO
TOTAL FOSSIL FUEL-INDUCED CO_2 RELEASE

The curves in Figure 5-4 were obtained by applying the pessimistic and optimistic assumptions concerning the global carbon cycle to the CO_2 emission levels of the two scenarios noted above. In only one of the four cases in Figure 5-4, the Low Growth Optimistic, would there be less than a doubling of atmospheric CO_2 levels by the year 2050. In the worst case, the High Growth Pessimistic, atmospheric CO_2 levels may increase nearly sixfold over the next 100 years.

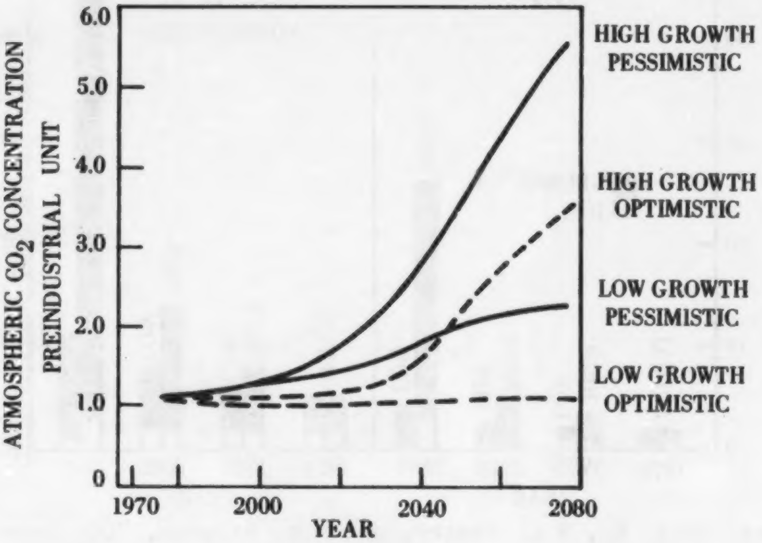


FIGURE 5-4
ATMOSPHERIC CARBON DIOXIDE CONCENTRATIONS—RANGE ANALYSIS

Atmospheric CO_2 levels are increasing, and continued increases could raise the average temperature of the earth's surface.[31] However, recent rises in atmospheric CO_2 levels have not been accompanied by observed rises in the earth's surface temperature. The magnitude of future increase, although highly uncertain, is expected to be greater at higher latitudes and less at the equator.[32] Available evidence also suggests that net global precipitation tends to increase as average temperatures rise.[33] Elevated temperatures may also cause changes in wind and ocean current patterns[34] and shifts in regional precipitation.[35]

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[31] U.S. Environmental Protection Agency, Coal Technology Assessment: First Year Report, in press. Also, Manabe, S. and R.T. Wetherald, "The Effects of Doubling the CO_2 Concentration on the Climate of a General Circulation Model," Journal of Atmospheric Science, Vol. 32, 1975, p. 3. Personal communication, D. Gates, 1979. Bolin, B., "The General Circulation of the Atmosphere and the Distribution of Climatic Zones," Annual Review of Energy, Vol. 2, 1977, pp. 202-218. Also, Keeling, C.D. and R.B. Bacastow, "Impact of Industrial Gases on Climate," Studies in Geophysics: Energy and Climate, National Academy of Sciences, Washington, D.C., 1977, p. 74. Mercer, J.H., "West Antarctic Ice Sheet and CO_2 Greenhouse Effect: A Threat of Disaster," Nature, Vol. 271, 1978, p. 321. Schneider, S.H., "On the Carbon Dioxide Climate Confusion," Journal of Atmospheric Science, Vol. 32, 1975. Schneider, reviewing a number of different models, indicates a range of 1.5°C-3.5°C for average temperature rise under conditions of doubled atmospheric CO_2.

[32] Manabe, S. and R.T. Wetherald, "The Effects of Doubling the CO_2 Concentration on the Climate of a General Circulation Model," Journal of Atmospheric Science, Vol. 32, 1975, p. 3-15. Personal communication, D. Gates, Professor of Botany and Director of Biological Field Station, University of Michigan, 1979. Also: Mercer, J.H., "West Antarctic Ice Sheet and CO_2 Greenhouse Effect: A Threat of Disaster," Nature, Vol. 271, 1978, p. 321. Schneider, S.H., "On the Carbon Dioxide Climate Confusion," Journal of Atmospheric Science, Vol. 32, 1975.

[33] Manabe, S. and R.T. Wetherald, "The Effects of Doubling the CO_2 Concentration on the Climate of a General Circulation Model," Journal of Atmospheric Science, Vol. 32, 1975, p. 3. Personal communication, D. Gates, 1979. Also: Kellogg, W.W., in J. Gribbin, ed., Climatic Change, Cambridge University Press, Cambridge, 1978.

According to the general circulation model cited previously,[36] a doubling of atmospheric CO_2 concentration leads to a temperature increase of approximately 2.5°C. Schneider, reviewing a number of different models, indicates a range of 1.5°C-3.0°C average temperature rise under conditions of doubled atmospheric CO_2.[37] Table 5-1 presents temperature ranges for low, mid, and high latitudes for various doublings of atmospheric CO_2 levels. These temperature figures represent the best estimates of experts in the field,[38] with a slight bias on the conservative side as noted previously.

Many factors compound the temperature effects from CO_2 alone. Release of other gases, notably nitrous oxide and aerosols, including chlorofluoromethanes, may enhance the "greenhouse effect." As global temperature increases, the earth's albedo may change because of snow and ice melt. Also, with rising temperature, the air's water-carrying capacity increases, resulting in more cloud cover and uncertain temperature feedbacks. Moreover, particles from fossil fuel combustion may screen out sunlight (thus changing albedo), perhaps negating to some extent any warming trends due to CO_2. Our understanding of these compounding factors is far from precise at present.

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[34] Bolin, B., "The General Circulation of the Atmosphere and the Distribution of Climatic Zones," Annual Review of Energy, Vol. 2, 1977, pp. 204. Also, Keeling, C.D. and R.B. Bacastow, 'Impact of Industrial Gases on Climate," Studies in Geophysics: Energy and Climate, National Academy of Sciences, Washington, D.C., 1977, p. 74.

[35] Kellogg, W.W., in J. Gribbin, ed., Climatic Change, Cambridge University Press, Cambridge, 1978.

[36] Manabe, S. and R.T. Wetherald, "The Effects of Doubling the CO_2 Concentration on the Climate of a General Circulation Model," Journal of Atmospheric Science, Vol. 32, 1975, p. 3-15.

[37] Schneider, S.H., "On the Carbon Dioxide Climate Confusion," Journal of Atmospheric Science, Vol. 2, 1975.

[38] Markley, O.W., A.L. Webre, R.C. Carlson, B.R. Holt, Sociopolitical Impacts of Carbon Dioxide Buildup in the Atmosphere Due to Fossil Fuel Combustion, discussion draft, prepared for U.S. Energy Research and Development Administration, 1977, p. 35. Table revised by R. Wetherald, R. Ramanthan, W.W. Kellogg, and J.M. Mitchell, Jr. Further revised by D.O. Gates, 1978, by extending the lower range of the optimistic estimates.

The global mean temperature rose about 0.6°C from the mid-1800s to 1940, and has since fallen about 0.3°C.[39] This recent cooling trend may be masking any CO_2-induced temperature rise. These variations may be natural or may be due to previously discussed factors such as particulates or cloud cover.

Figure 5-5 translates the global atmospheric CO_2 increases shown in Figure 5-4 to temperature changes over time (using the midlatitude temperature estimates from Table 5-1). In contrast to Figure 5-4, in which considerable overlap is seen between optimistic and pessimistic projections of CO_2 concentration, the distribution of curves in Figure 5-5 is more consistent, with a marked separation between optimistic and pessimistic projections. The amount of temperature rise in 1975 is uncertain, as is reflected in the different "starting points" for the optimistic and pessimistic curves in Figure 5-5. Although the earth's temperature in 1975 was measured and known, the effects of CO_2 alone may have been offset by cooling trends, as has been discussed. The optimistic curves show an initial negative slope, reflecting the possibility of terrestrial plant uptake acting as a CO_2 sink before the effect is overwhelmed by the CO_2 release from increasing fossil fuel use.

A few conclusions may be drawn from Figure 5-5. First, uncertainty about the global CO_2 problem is so extensive that at one extreme, CO_2 effects apparently will become very severe by 2030; while at the other extreme, CO_2 may not be a problem of concern. Second, if the world follows the high fossil fuel use scenario, a 2°C average temperature rise (closer to 10°C near the polar regions) could occur within 75 years, even with consistently optimistic assumptions. And finally, with pessimistic assumptions, average global temperature rise could exceed 2°C by the year 2030, even if the world follows the low energy use path.

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[39] Mitchell, J.M., Jr., "Natural Breakdown of the Present Interglacial and its Possible Intervention by Human Activities," Quaternary Research, Vol. 2, 1972, p. 436. Also, W.S. Broecker, "Climatic Change: Are We On the Brink of a Pronounced Global Warming?" Science, Vol. 189, 1975, p. 462.

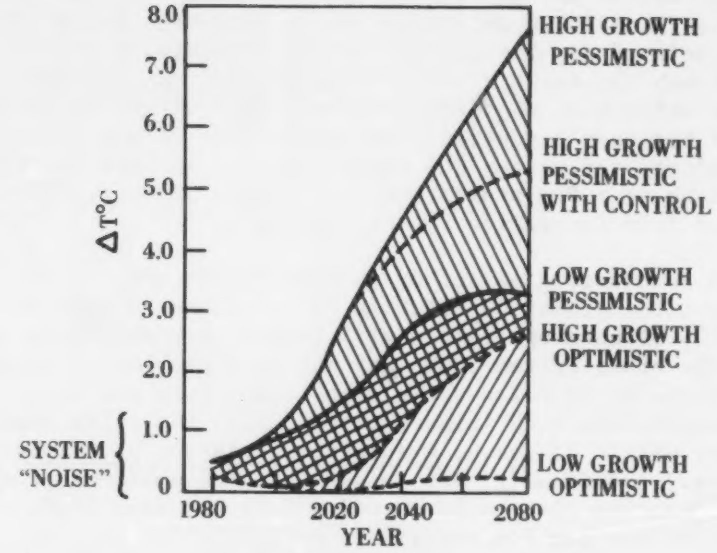

FIGURE 5-5
TEMPERATURE RANGE ANALYSIS

5.2.4 Impacts and Implications

Agriculture

Regional shifts in temperature and precipitation could have great impacts on agriculture. For example, under warmer or dryer conditions, decreased yields have been noted for widely used strains of corn and rice, but increased yields for wheat.[40] Productivity increases with increased atmospheric CO_2 concentrations. Therefore, moderate increases in CO_2 could be beneficial, on balance, to agricultural productivity. Over the long term, regional climatic shifts may require development of new crop strains or use of different agricultural management practices. Such shifts could change the relative distribution of major world food supply regions. Certain areas that could conceivably benefit from CO_2-induced climatic effects may possess less fertile soils and lack the infrastructure necessary for large-scale agricultural production. The combination of these factors could lead to disrupted international food markets, food shortages, or rationing. Alternatively, over the long term, a wetter and warmer climate could mean net global increases in agricultural yield.

Even over the short term, climatic transition can affect the fragile global food supply network; for example, in 1971 and 1972, temperatures deviated as much as 0.8°C below normal in the Northern Hemisphere.[41] Severe monsoons, followed by drought, led to a disappointing rice crop in Southeast Asia; the Soviet wheat crop was devastated by cold and low precipitation; drought continued in North Central Africa; crop yields were below normal in India; and anchovy fisheries failed off the coast of Peru. Famine was commonplace in India and Africa, and food prices rose sharply in the United States.[42]

Hydrology

Changes in regional hydrology, as in the water-limited western United States, and rising sea levels due to polar ice melt are possible impacts of increased atmospheric CO_2. Shoreline development, recreation, agriculture, water-intensive energy and industrial facilities, and resident populations could be affected. Areas dependent on spring stream runoff for yearly water supplies would be particularly susceptible to warmer climates; under appropriate conditions, impacts could result within a few years. Sea-level rises would occur over a longer term. Mercer notes that the unique characteristics of the West Antarctic ice sheet make it more vulnerable to oceanic and atmospheric warming than other ice sheets.[43] Complete melting or the break-off of the West Antarctic ice sheet alone could cause a 5-meter sea level rise for the United States, displace some 11 million people, affect $110 billion of property, and threaten as many as 10 nuclear reactors.[44]

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[40] Bach, W., in J. Williams, ed., Carbon Dioxide, Climate, and Society, Pergamon Press, Oxford, 1978, pp. 153-158.

[41] Bolin, B., "The General Circulation of the Atmosphere and the Distribution of Climatic Zones," Annual Review of Energy, Vol. 2, 1977, p. 203. See also Figure 5-3.

[42] Shapley, D., "Will Fertilizers Harm Ozone as Much as SST?", Science, Vol. 195, 1977, p. 377. Also, W. Bach, in J. Williams, ed., Carbon Dioxide, Climate, and Society, Pergamon Press, Oxford, 1978, p. 161.

Possibility of Thresholds in the Global Carbon Balance

Shorter term temperature rises may be of grave concern if thresholds exist in the global carbon balance. For example, in the late Mesozoic Era, deep oceanic waters may have been triggered into releasing vast amounts of CO_2 into the atmosphere in a positive feedback between climatic warming and CO_2 expulsion.[45] It has also been suggested that a minor percentage shift in carbon held in terrestrial debris could result in large releases of CO_2.[46] The possibility that relatively small temperature changes may create positive feedback effects dictates caution in projecting time horizons for potential CO_2 impacts.

Sociopolitical Impacts

These possible agricultural and biophysical impacts could create profound consequences for humanity. Famine, political dissension, mass population migration, and shifting world power balances are only a few of the possible consequences. If CO_2-induced climatic changes were to occur, a global challenge of unprecendented scale would arise.

No single country alone can, by abstention from fossil fuel use, keep global CO_2 effects within nonconsequential limits if the rest of the world follows the high energy use scenario. The most far-ranging implication of CO_2-induced effects may be the need for the global community to learn to live with a warmer climate.

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[43] Mercer, J.H., "West Antarctic Ice Sheet and CO_2 Greenhouse Effect," Nature, Vol. 271, 1978, p. 321.

[44] Schneider, S.H. and K. Chen, American Association for Advancement of Science Meeting, as reported in Technology Review, March and April 1979, p. 82.

[45] McLean, D.M., "A Terminal Mesozoic Greenhouse: Lessons From the Past," Science, Vol. 201, 1978, p. 405.

[46] Schlesinger, W.H., "Carbon Balance in Terrestrial Detritus," Annual Review of Ecology Systematics, Vol. 8, 1977, p. 75.

5.3 ACID DEPOSITION

HIGHLIGHTS OF SECTION 5.3

- Nitrogen and sulfur oxides are unstable in the troposphere and form compounds which can increase acidity of rain water and surface water on continental scales.

- Acid deposition has become a problem in both North America and in Europe. Surface deposits from precipitation (rain or snow), dry deposition (gases or particulates), and special events (dews, fogs, frosts, etc.) are becoming more acidic both in time and space.

- At present, sulfur and nitrogen compounds are the main contributors to the acid deposition problem. Sulfur emissions are expected to level out throughout the 1980s, while nitrogen emissions continue to increase; thus, the nitrogen species should become more significant in total contribution to the problem.

- Acid deposition has had substantial adverse effects on the environment: acidification of lakes, rivers, and ground waters, with resultant damage to the aquatic ecosystem; acidification and demineralization of soils; reduction of forest productivity; damage to crops; and deterioration of materials. These effects may be cumulative or result from peak acidity episodes. Prediction of the distribution or intensity of acid rain remains outside current modeling capabilities.

5.3.1 Problem Identification and Regulatory Background

Acid deposition is a major environmental problem on both sides of the Atlantic Ocean. First noticed and studied in the Scandinavian countries and in Canada, acid deposition has now been documented in this country, first in the Northeast and now, apparently through much of the United States east of the Mississippi. Increasing acidic deposition has already caused measurable damage to aquatic ecosystems and has the potential for longer term injury to forest ecosystems. In addition, acidic deposition is contributing to the corrosion of materials, degradation of sensitive soils, and damage to agricultural crops. Acid deposition was recently cited as a major regional environmental problem by President Carter.[47]

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[47] The President's message to Congress on 2 August 1979 recommended a 10-year comprehensive Federal Acid Rain Assessment Program. This program is managed by an Acid Rain Coordination Committee, with the Environmental Protection Agency and the U.S. Department of Agriculture cochairing this committee, and the Council on Environmental Quality serving as executive secretary.

This discussion concentrates on the precipitation component of the acid deposition problem, for this area is the best understood and most intensely studied today. It is universally agreed that the dry deposition component (particulate sedimentation/impaction and/or gaseous absorption) is a significant contributor to the overall deposition of acidic materials. Other events such as dews, frosts, and fogs also contribute to the total deposition. Both dry deposition and special acidic events need to be studied, immediately and intensively, to determine their overall contribution to the total acid deposition problem.

By definition, a neutral water sample would register a pH of 7. However, in the atmosphere, rain water naturally registers a pH of 5.65, because of an equilibrium reached with ambient concentrations of carbon dioxide present in the atmosphere. Therefore, precipitation that registers a pH below 5.65 is defined as acidic.

Currently, pH values in the low 4s are being recorded in most of northern Europe, the northeastern United States, and southeastern Canada; these areas are considered to have the greatest acidity problem. In addition, pH values much lower than these are being observed during individual storms. The main acidity contributors are the following substances:[48]

Sulfur compounds: SO_2, $SO_3^{=}$, $SO_4^{=}$, HSO_4^-, H_2SO_4

Nitrogen compounds: Nitric oxide (NO), nitrogen dioxide (NO_2), NO_2^-, NO_3^-, HNO_3, NH_4^+

Chlorine compounds: HCl

Others: Weak acids (e.g., organic acids, H_2CO_3); Bronsted acids (e.g., dissolved Fe^{3+}, NH_4^+)

The precipitation acidity seen today primarily results from the gaseous products of combustion, SO_2, NO_x (NO and NO_2), being oxidized to H_2SO_4 and HNO_3, respectively, within the atmosphere and ultimately being deposited on the land or surface waters by precipitation (Figure 5-6).

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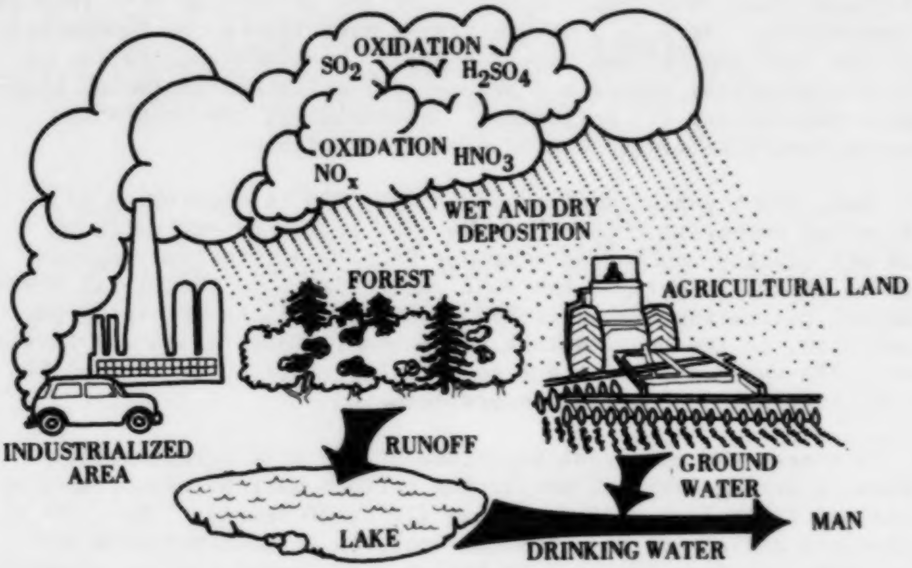
[48] Whelpdale, D.M., Proceedings from the Workshop on Ecological Effects of Acid Precipitation, EPRI SOA-77-403, Electric Power Research Institute, Palo Alto, California, 1978.



OXIDATION
SO_2
H_2SO_4
OXIDATION
HNO_3
NO_x
WET AND DRY DEPOSITION
FOREST
AGRICULTURAL LAND
INDUSTRIALIZED AREA
RUNOFF
GROUND WATER
LAKE
DRINKING WATER
MAN

FIGURE 5-6
FORMATION AND DEPOSITION OF ACIDIC COMPONENTS

No U.S. environmental regulations now directly address the acid precipitation problem. A criteria document on particulates and sulfur oxides, currently being updated by EPA's Environmental Criteria and Assessment Office (ECAO), will contain a chapter on acid precipitation clearly marking it as a current major concern.

On the international level, the signing of the Convention on Long-Range Transboundary Air Pollution by member countries in Geneva during the 13-16 November 1979 meeting of the U.N. Economic Commission for Europe's High Level Meeting on Protection of the Environment is a significant step toward recognizing the problem of acid rain and its precursors. Article 2 of the treaty establishes the fundamental principle that the parties "shall endeavor to limit and, as far as possible, gradually reduce and prevent air pollution including long-range transboundary air pollution." Essentially, the treaty is directed toward solving the acid deposition problem.

Also, under annual written agreement, EPA is continuing to process and summarize sulfur dioxide data collected worldwide by urban air quality monitoring stations in 43 countries and regions. This EPA effort is part of the U.S. contribution to the Global Environmental Monitoring System (GEMS) of the UN's Earthwatch program. In addition, in the Organization for Economic Cooperation and Development, EPA expects to continue cooperative research efforts on SO_x and NO_x international pollution problems.

To assess the potential magnitude of the acid precipitation problem, a strong national monitoring network must be established and maintained for a long period of time (10 to 20 years). This will involve the collection and chemical analyses of precipitation samples, with all sites required to follow a stringent quality control/assurance procedure in the collection, handling, storage, and analysis of the samples. EPA is in the early stages of establishing this network.

Along with the monitoring and measuring described above, a total acid deposition research program will include study of atmospheric processes and impacts. Much needs to be learned about chemical transformation processes, transport of the acidic components, and mechanisms of deposition. When these areas of knowledge are integrated, acid deposition models can be designed. Knowledge of agricultural effects; impacts on forest systems, watersheds, and aquatic systems; structural materials; and impact on drinking water supplies is limited. Emphasis will be placed on gaining understanding about these potentially impacted areas.

5.3.2 Emission Trends

The emission trends of the two chief contributors to acid precipitation--SO_x and NO_x--are the focus of this discussion. Ambient SO_x and NO_x levels result from both natural sources and human activities. The magnitude of SO_x and NO_x emissions from natural sources is uncertain. Therefore, any correlations made between precipitation concentrations and emissions from industrial sources must be considered as relative.

During the late 1950s, sulfates were the main contributors to precipitation acidity in the northeastern United States. Since that time, nitrates have contributed increasingly to acidity, and in the early 1970s accounted for 30 to 35 percent of the acidity. Figures 5-7 and 5-8 are graphs of projected SO_2 and NO_x emissions from 1975 through 1990. These projections are based on the Energy Information Administration's Series C energy projections, which posit a total energy supply of 111 quads by 1990, of which coal would contribute 25 percent, crude oil 16 percent, and natural gas 15 percent. This is generally consistent with High Growth assumptions used elsewhere in this report: 124 quads total supply by 2000, 44 quads of which would be coal, 44 quads oil, and 18 quads gas. As the curves show, SO_x emissions are expected to flatten out during this period, while NO_x emissions are expected to continue their much steeper increases. The emission projections in Figure 5-8 indicate that nitrogen compounds will continue to increase their contribution to overall precipitation acidity.

5.3.3 Acid Precipitation Trends

The first historical reports of acid precipitation were recorded in the early 1900s in the industrial town of Leeds, England, where pH measurements of 3.2 were found.[49] Scientific interest was not widely stimulated, however, until pH values of 3.5 were recorded in the Scandinavian region in the early 1950s.[50] The problem of acid precipitation in the United States did not really become apparent until systematic biogeochemical cycling studies were initiated at Hubbard Brook Experimental Forest, New Hampshire, in the early 1960s;

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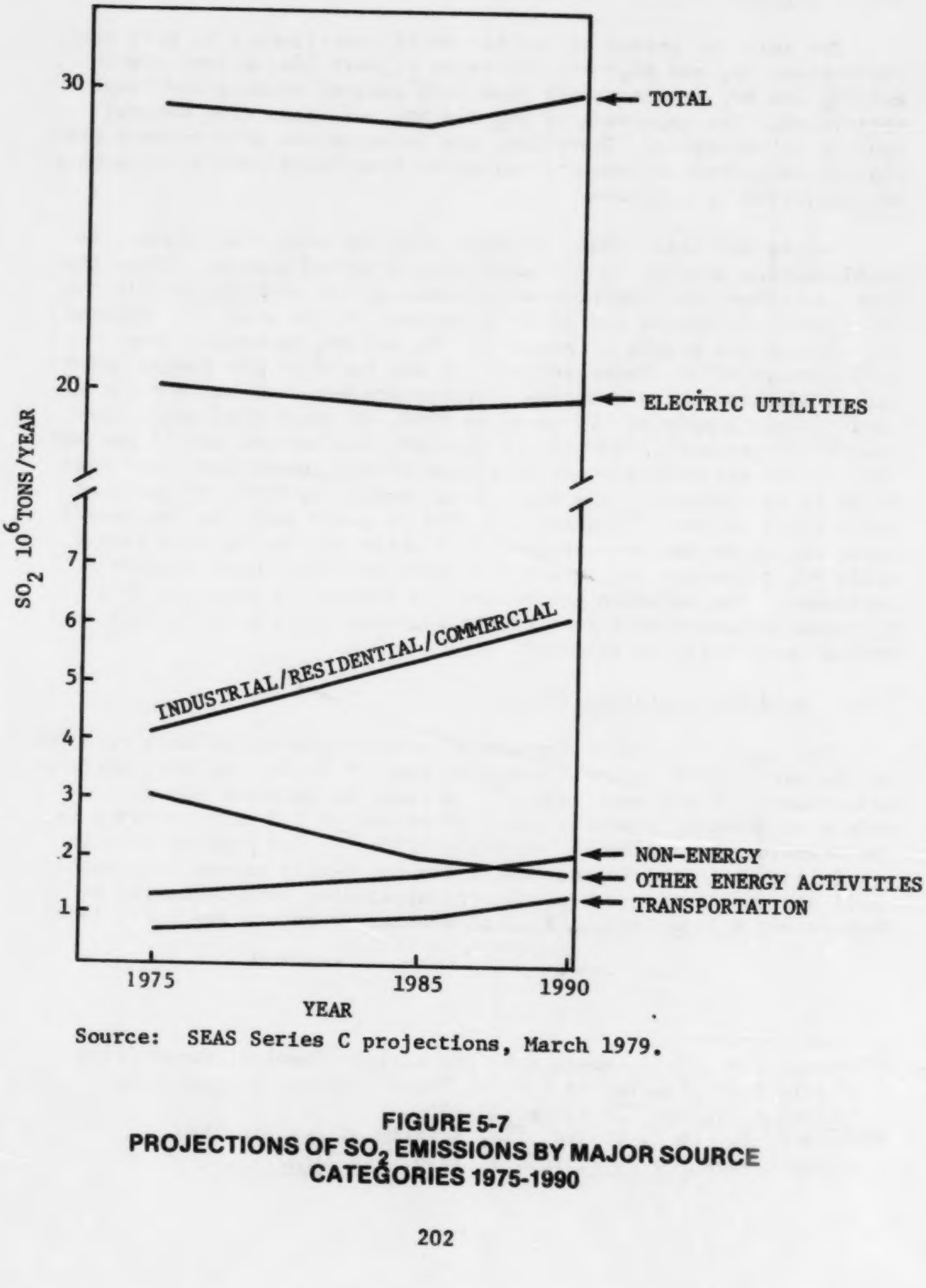
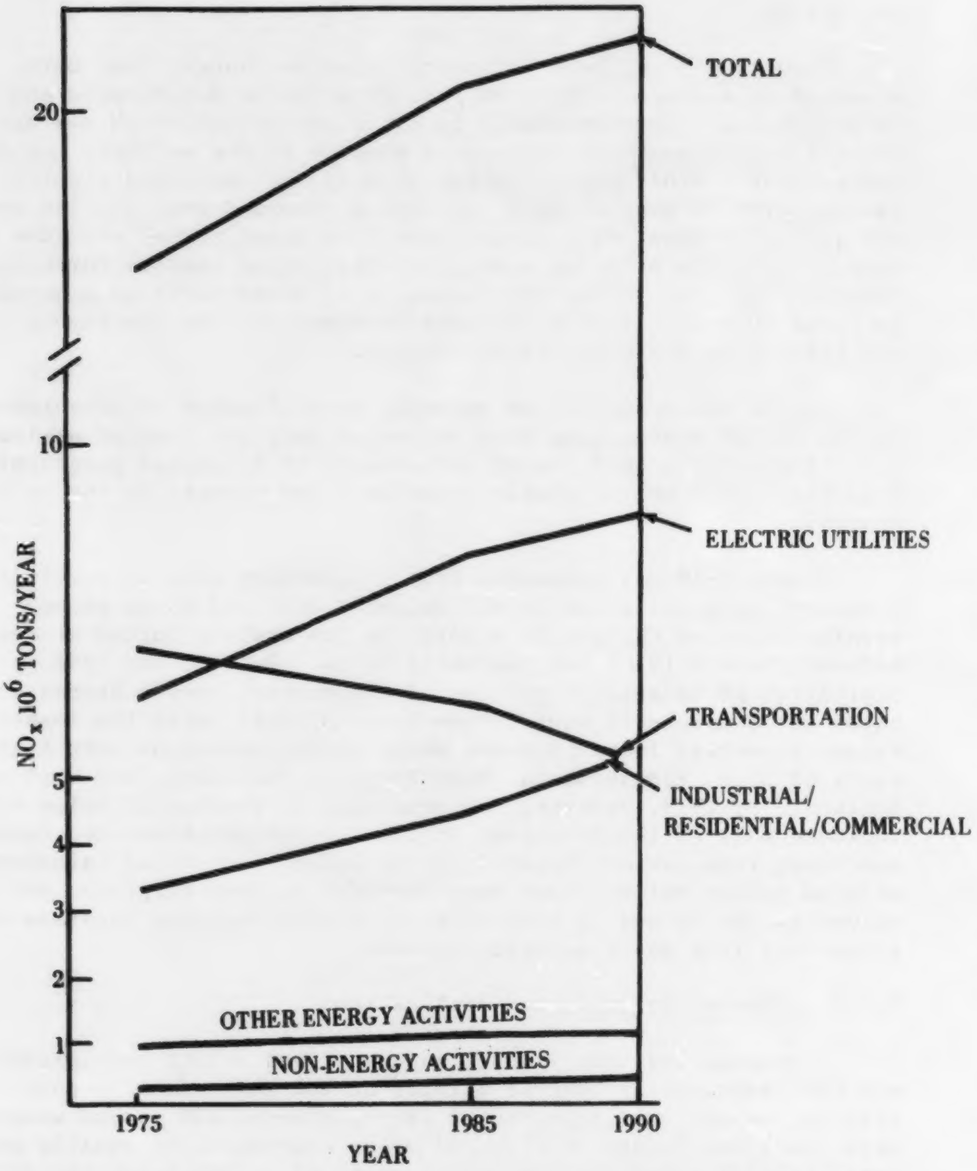
[49] Cooper, H.B., J.A. Lopez, and J.M. Denio, "Chemical Composition of Acid Precipitation in Central Texas," Water, Air and Soil Pollution, Vol. 6, 1976, pp. 351-359.

[50] Barrett, E. and G. Brodin, "The Acidity of Scandinavian Precipitation," Tellus, Vol. 7, 1955, p. 251-257.



Source: SEAS Series C projections, March 1979.

FIGURE 5-7
PROJECTIONS OF SO_2 EMISSIONS BY MAJOR SOURCE CATEGORIES 1975-1990



Source: SEAS Projections Based on EIA Series C Forecasts, March 1979.

FIGURE 5-8
PROJECTIONS OF NO$_x$ EMISSIONS,
BY MAJOR SOURCE CATEGORIES, 1975-1990

measurements there revealed strongly acidic precipitation with pH in the low 4s.[51]

Figures 5-9 and 5-10 delineate relative changes that have occurred in average acidity in precipitation in Scandinavia and the United States. In Scandinavia in 1957, precipitation pH averaged about 5 in the southern regions to about 6 in the northern regions; years later (1970), precipitation acidity had increased significantly, with an average pH of 4.5 being recorded over all the southern areas. Figure 5-9 presents data from Scandinavian stations that have collected continuous monthly precipitation samples throughout this period. The acidic precipitation in Scandinavia is generally believed to result from pollutants transported from the highly industrialized areas of western Europe.

Unlike the Scandinavian network, precipitation pH measurements in the United States have been collected only for limited periods of time (typically 1 to 2 years) and usually in a limited geographical area (typically only a single point or a few points, in one or two states).

Figure 5-10 was assembled from fragmentary sets of precipitation chemistry data collected in the United States and is an attempt to display relative changes in acidity in the eastern United States between the mid-1950s and the early 1970s. In 1955 and 1956, precipitation pH in a large portion of the eastern United States was below the atmospheric equilibrium value of 5.65, with the lowest pH values generally found in zones where sulfur emissions were highest--parts of Ohio, Pennsylvania, West Virginia, New York, and most of New England. By 1973, however, the area with an average pH below 4.5 included most of the area east of the Mississippi River and extended northward into eastern Canada. In addition, individual rainstorms with pH values below 2 have been recorded in West Virginia, and values in the 2s and 3s have been registered in areas hundreds of kilometers from major emission sources.

5.3.4 Effects, Impacts, and Implications

A growing body of evidence suggests that acidic precipitation may have substantial adverse effects on the environment. Such effects include acidification of lakes, rivers, and ground waters, with resultant damage to fish and other components of aquatic ecosystems; acidification and dimineralization of soils; reduction of forest productivity; damage to crops; and deterioration of man-made

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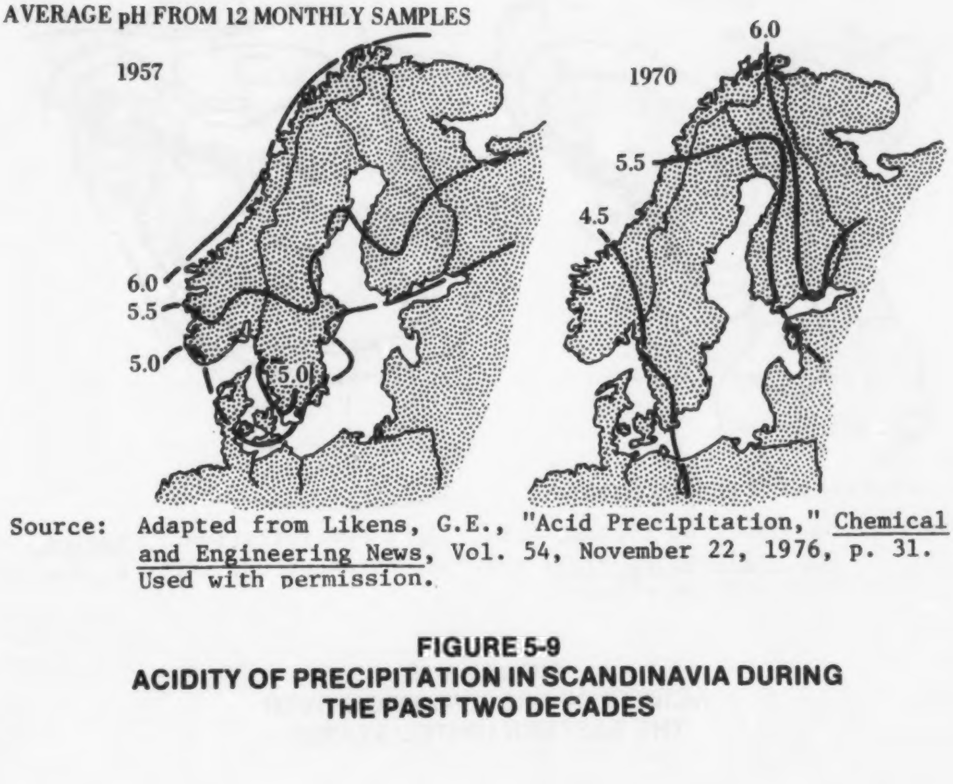
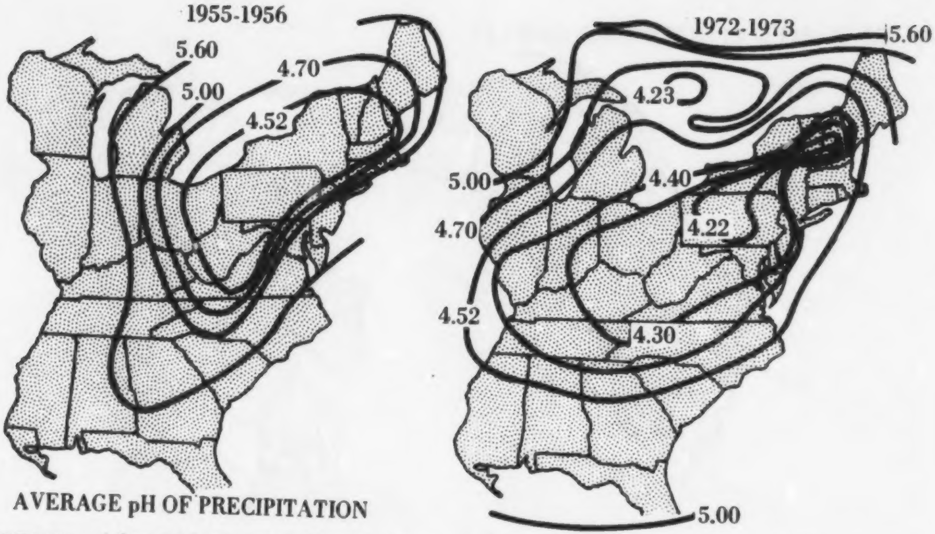
[51] Likens, G.E., F.H. Borman, and N. Johnson, "Acid Rain," Environment, Vol. 14, 1972, pp. 33-40.


AVERAGE pH FROM 12 MONTHLY SAMPLES
1957
6.0
5.5
5.0
5.0
1970
6.0
5.5
4.5

Source: Adapted from Likens, G.E., "Acid Precipitation," Chemical and Engineering News, Vol. 54, November 22, 1976, p. 31. Used with permission.

FIGURE 5-9
ACIDITY OF PRECIPITATION IN SCANDINAVIA DURING THE PAST TWO DECADES


1955-1956
5.60
4.70
5.00
4.52
1972-1973
5.60
4.23
5.00
4.40
4.22
4.70
4.52
4.30
5.00
AVERAGE pH OF PRECIPITATION

Source: Adapted from Likens, G.E., "Acid Precipitation," Chemical and Engineering News, Vol. 54, November 22, 1976, p. 31. Used with permission.

FIGURE 5-10
ACIDITY OF PRECIPITATION OVER THE EASTERN UNITED STATES

materials. These effects may be cumulative or may result from peak acidity episodes.[52] Uncertainties and insufficient knowledge in each of these areas point up the need for continued study of all potentially impacted systems.

Aquatic Ecosystems

Freshwater bodies in much of eastern North America and northern Europe, which today lie within and adjacent to the areas of most acid precipitation, are threatened by the continual deposition and further expansion of acid precipitation. Most of these bodies of water are in regions underlain by carbonate-poor granitic rock and are poorly buffered and vulnerable to acid inputs.[53] The increasing acidity of lakes in North America and Europe has been documented; the most tangible result is the decline in fish populations.[54] Figure 5-11 shows the frequency distribution of pH in New York State lakes between the 1930s and 1970s. Figure 5-12 shows the resultant fish population present with varying lake pHs. Note that as the pH drops below 5, the fish populations rapidly diminish.

Other evidence indicates that not only are fish affected by acidification, but the balance of the many life forms in the aquatic ecosystem are also affected. The number of invertebrates decreases, and the rate of decomposition of organic matter slows, as bacteria become less dominant in relation to fungi. Some observers also believe that the slower decomposition of organic matter and the increase in various species of algae and fungi on lake bottoms together reduce the cycling of nutrients and lead to a depletion of nutrients and decreased biomass productivity.[55]

Acid precipitation causes other changes in lake-water chemistry. Elevated concentrations of heavy metals have frequently been observed in acidified lakes. These higher concentrations may result from either direct atmospheric deposition or from the increased solubility of sediments found in acidic lakes. These additional heavy

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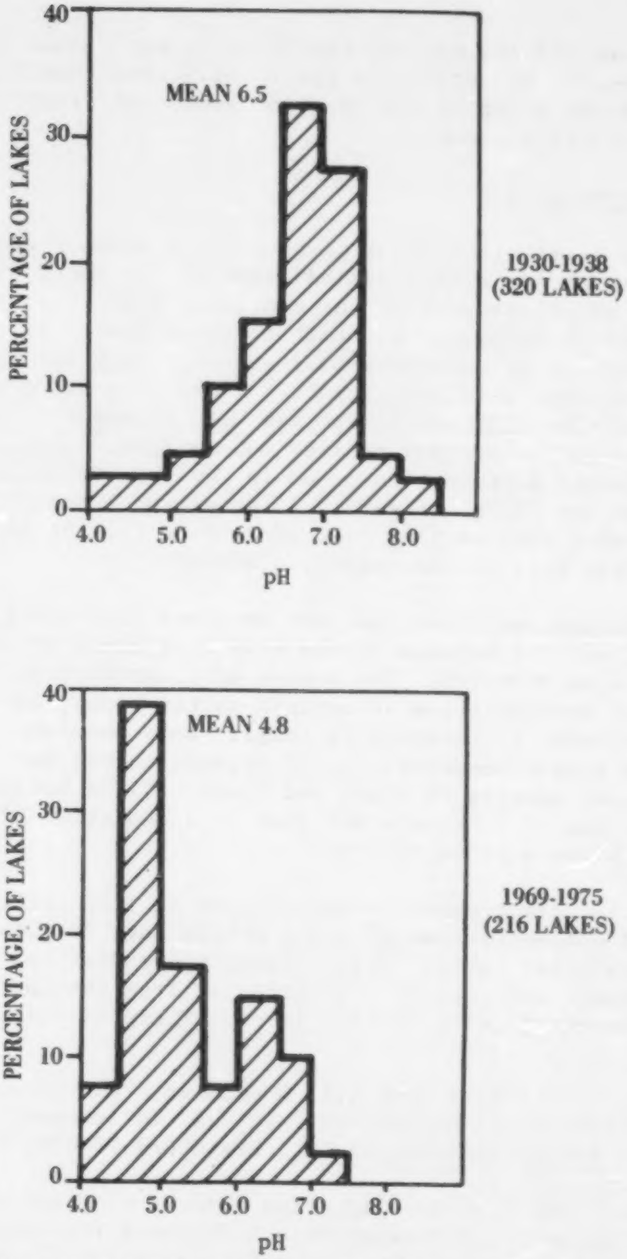
[52] Glass, N.R., G.E. Likens, and L.S. Dochinger, "The Ecological Effects of Atmospheric Deposition," in U.S. Environmental Protection Agency, Energy/Environment III, EPA-600/9-78-002, 1978, pp. 113-139.

[53] Galloway, J.N. and E.B. Cowling, "The Effects of Precipitation on Aquatic and Terrestrial Ecosystems: A Proposed Precipitation Chemistry Network," J. Air Pollution Control Association, Vol. 28, March 1978, pp. 229-235.

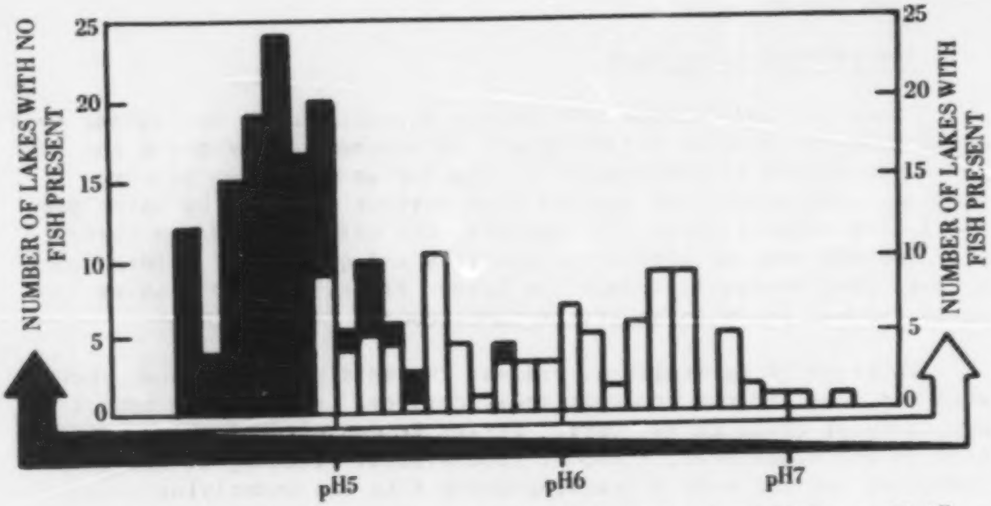
[54] Likens, G.E., "Acid Precipitation," Chemical and Engineering News, Nov. 22, 1976, pp. 29-44.

[55] Ibid.



Source: Adapted from Schofield, C.L., "Acid Precipitation Effects on Fish" Ambio, Vol. 5, 1976, pp. 228-230. Used with permission.

FIGURE 5-11
FREQUENCY DISTRIBUTION OF pH IN LAKES
IN THE ADIRONDACK MOUNTAINS, NEW YORK



Source: Adapted from Schofield, C.L., "Acid Precipitation Effects on Fish" Ambio, Vol. 5, 1976, pp. 228-230. Used with permission.

FIGURE 5-12
DISTRIBUTION OF pH AND FISH POPULATION STATUS IN ADIRONDACK MOUNTAIN LAKES DURING THE SUMMER OF 1975

metals may represent a major physiological stress to various aquatic organisms.[56]

The concern about the deposition of heavy metals, and also organic chemicals and nutrients, has been elevated by a pilot assessment of ambient conditions conducted by EPA's Office of Water and Waste Management. That pilot study found high levels of metals in surface waters in several "pristine" areas. Both direct deposition of metals from the atmosphere and mobilization of metals by acidity are possible causes. Further discussion may be found in Sections 4.7.4 and 6.2.8.

Terrestrial Ecosystems

There are indications that acidic deposition may be leading to a decline in the rate of forest growth in southern Scandinavia and in the northeastern United States.[57] The forest ecosystem is very complex. Different tree species have various pathways by which precipitation affects them. For example, the different canopy covers that forests present affect the quantity and quality of acidic components that eventually reach the forest floor.[58] This problem needs further study to be better understood.

In terms of agricultural yields, the acidic depositional phenomenon may have serious economic ramifications. Acidity can impact agricultural crops in two ways. First, it can directly cause mutilation of the plant leaf, stem, or root system. Second, it can indirectly affect the crop by causing changes in the underlying soil properties, thereby changing the type and/or rate of nutrients cycled through the crops. Uncultivated crops such as range grasses are of greatest concern. Combined controlled field and laboratory crop studies are currently being undertaken. These experiments involve exposing designated crops to a series of variable-pH simulated rainfalls and measuring their overall growth, weight, and yield. Results from preliminary studies indicate decreased productivity for some crops continually exposed to more acidic rains, and increased productivity for others.[59]

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[56] Glass, N.R., G.E. Likens, and L.S. Dochinger, "The Ecological Effects of Atmospheric Deposition," in U.S. Environmental Protection Agency, Energy/Environment III, EPA-600/9-78-002, 1978, pp. 113-139.

[57] Tamm, C.O., "Acid Precipitation: Biological Effects in Soil on Forest Vegetation," Ambio, Vol. 5, 1976, pp. 235-238.

[58] Dochinger, L.A. and T.A. Selega, eds., Proceedings of the First International Symposium on Acid Precipitation and the Forest Ecosystems, USDA Forest Service General Technical Report NE 23, Northeastern Forest Exp. Station, Upper Daly, Pennsylvania, 1976.

Effects on Materials

Acidic deposition may result in extensive damage to buildings, statues, and the like, through degradation of metals, paints, stones, and other materials. The Parthenon in Athens, which has aged more during the past century than during all its previous existence may be an example of acid deposition-caused degradation. However, various kinds of atmospheric pollution in recent times can combine to cause damage. In stone and marble, the sulfate ion in precipitation or dry deposition replaces the carbonate ion in $CaCO_3$ rendering the surface more easily eroded. In metals, the surface is spoiled by electrolytic corrosion due to exposure to acidic compounds.

Acid deposition effects on materials have not yet been quantified, but indications are that acid precursor gases (SO_2 and NO_x) and particulate matter produced from coal combustion do damage various materials.[60] Substantiation of this kind of evidence would underscore the potential for significant economic loss from damage to materials by acid deposition.

5.4 STRATOSPHERIC OZONE

HIGHLIGHTS OF SECTION 5.4

- Chlorofluorocarbons[61] are stable in the troposphere but are photodisassociated in the stratosphere. The halogens released, primarily chlorine, are expected to cause the reduction of the ozone concentrations of the stratosphere, thereby increasing ultraviolet radiation at the ground.

- Reduction of ozone by other mechanisms has also been predicted, but chlorofluorocarbon release remains the issue of most concern. Legislative and regulatory action has been taken to lower chlorofluorocarbon emission rates.

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[59] Lee, J.J., personal communication, crop yield and foliar injury study, U.S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, Oregon, summer 1979.

[60] Glass, N.R., "Identification and Distribution of Inorganic Components in Water: What to Measure?", Annals of the New York Academy of Sciences, Vol. 298, 1977, p. 31.

[61] The word chlorofluorocarbon refers to the general category of chlorofluoroalkanes, which include chlorofluoromethanes (CFM). Other terms used in identifying these gases include halocarbons and Freon© (or other trade names).

o The incidence of increased ultraviolet radiation will result in reduced productivity in agriculture, adverse effects on some marine life forms and increased incidence of cancer in humans and other animals. Slight climatic effects in the form of global atmospheric warming are also predicted.

5.4.1 Introduction

Small concentrations of ozone (O_3) in the stratosphere provide vital protection for the entire biosphere, including man, from the sun's ultraviolet (UV) radiation. Although the harmful effects of excessive ultraviolet exposure (e.g., sunburn) have been known for many years, the potential for man's activities to decrease ozone, permitting the penetration of the more damaging portion of the solar ultraviolet radiation spectrum, has been suggested only recently. A number of mechanisms for ozone depletion have been cited in the scientific literature; the most important appears to be the release of chlorofluorocarbon gases in the atmosphere.

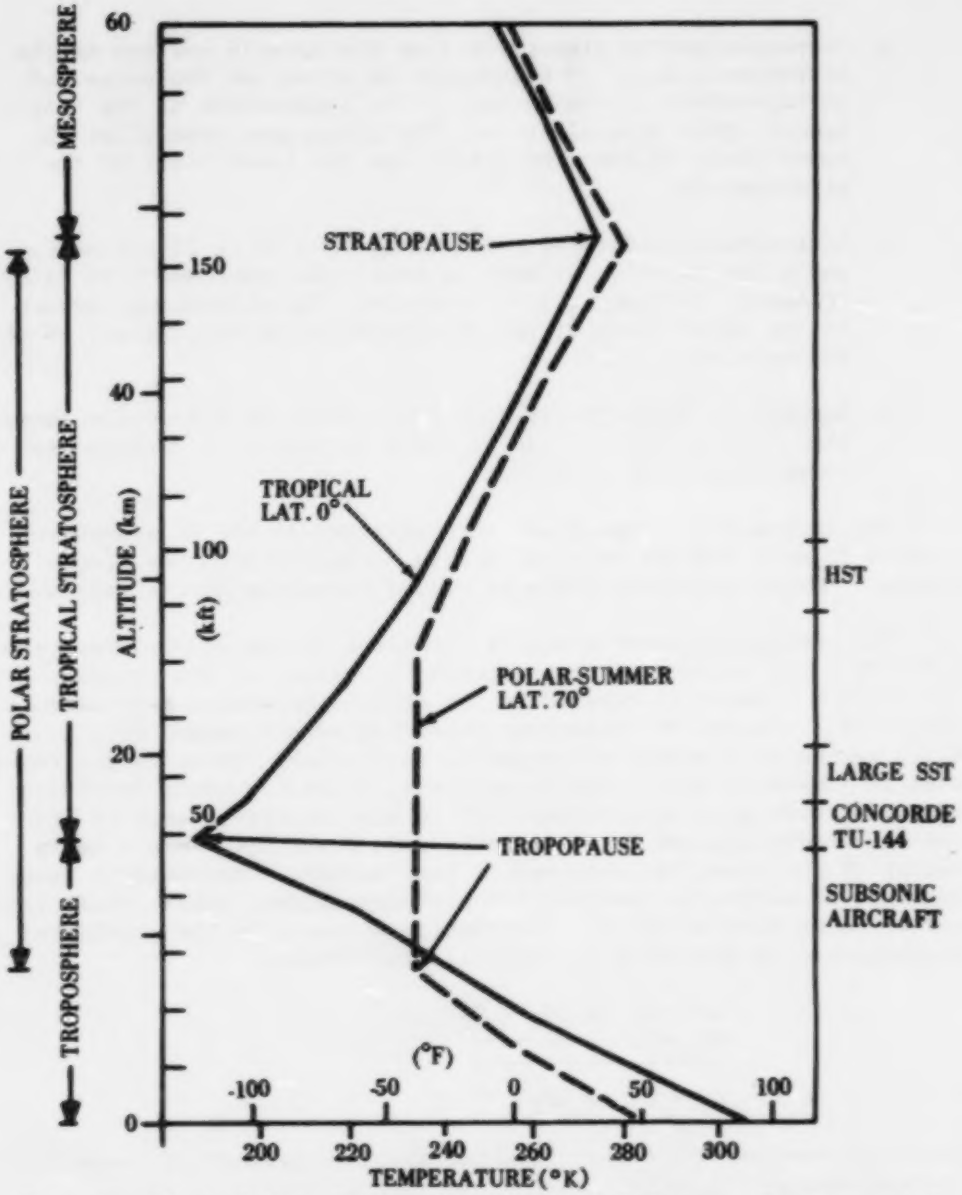
5.4.2 Problem Identification and Regulatory Background

Chlorofluorocarbons released in the lower atmosphere migrate to the stratosphere where they are decomposed by the intense solar ultraviolet radiation that does not penetrate the ozone layer to reach the earth's surface. The chlorine in these compounds is released and participates in ozone destruction.

Ozone depletion resulting from other of man's activities (such as stratospheric aircraft flights, rocket launching, use of large quantities of nitrogen fertilizers, and release of other halogen gases) has also been predicted. The threat associated with these potential ozone-depleting activities is currently considered small compared to the expected effects of chlorofluorocarbon release. Note, however, that estimating the size of the threat from any of these processes involves prediction based on limited facts and understanding. For example, early ozone depletion estimates were modified considerably as knowledge increased, and additional changes were revealed. The uncertainty about the magnitude of possible effects requires that suspect processes or pollutants be scrutinized.

The Unpolluted Stratosphere

The stratosphere can be described most conveniently in terms of its composition and temperature structure and that of the rest of the atmosphere (see Figure 5-13). The atmosphere of the earth has three distinct vertical regions:



Source: Adapted from National Academy of Sciences, Environmental Impact of Stratospheric Flight, Washington, D.C., 1975.

FIGURE 5-13
THE ATMOSPHERE'S TEMPERATURE/ALTITUDE PROFILE

- Troposphere--The atmosphere from the earth's surface to the tropopause, about 19 kilometers in extent at the poles and 10 kilometers at the equator. The temperature of the troposphere drops with altitude. The tropopause identifies the upper limit of the troposphere and the lower limit of the stratosphere.

- Stratosphere--Atmosphere extending from 10 to 24 kilometers above the earth's surface, in which the temperature is fairly constant, increasing with altitude. The stratopause occurs at the upper limit of the stratosphere and lower limit of the mesosphere.

- Mesosphere--Atmospheric zone about 24 to 80 kilometers above the earth's surface. It is characterized by a decrease in temperature with altitude.

The increase in temperature with altitude in the stratosphere results in very limited vertical mixing, compared with the troposphere. Hence, residence times of stable compounds can be very high.

The concentration of ozone at any point in the stratosphere results from the balance of the competing processes of its creation and destruction. Ozone is created in the stratosphere when molecular oxygen (O_2) absorbs UV radiation, producing atomic oxygen (O), which reacts with molecular oxygen to form ozone. Ozone is destroyed when it interacts with certain compounds, primarily those involving nitrogen, hydrogen, or chlorine. It is also destroyed when it absorbs UV radiation and is dissociated into O and O_2. Only a small amount of the ozone is destroyed in this manner. The dominant ozone destruction mechanism involves the nitrogen oxides, nitric oxide (NO) and nitrogen dioxide (NO_2). Destruction of ozone in the unpolluted stratosphere is dominated by the following process:

$$\begin{array}{lll} & NO + O_3 & = NO_2 + O_2 \\ & \underline{NO_2 + O} & \underline{= NO + O_2} \\ \text{Net:} & O_3 + O & = 2O_2 \end{array}$$

These conversions are responsible for about 70 percent of ozone destruction.

In converting the ozone to molecular oxygen, the nitrogen compounds are conserved and so act in a catalytic manner. Each molecule of NO can participate in the destruction of many ozone molecules before it reacts with other stratospheric constituents to form nitric acid, which is removed by tropospheric rain processes, assuming that the acid reaches the troposphere.

A less important ozone-destroying process involves the catalytic action of hydroxyl (HO) and hydroperoxyl (HO_2), wherein hydrogen replaces nitrogen in the equations above.

Chlorine (Cl) also participates in removal of ozone in the stratosphere. The processes are as follows:

$$\begin{array}{lll} & Cl + O_3 & = ClO + O_2 \\ & ClO + O & = Cl + O_2 \\ \hline \text{Net:} & O_3 + O & = 2O_2 \end{array}$$

As in the case of nitrogen compounds, the catalytic agent, Cl, remains available to repeat its role in this process.

The sources of compounds that result in catalytic removal of ozone have been extensively studied. The hydrogen species result from water vapor (H_2O), methane (CH_4), and a photochemical process involving atomic oxygen. The nitrogen compounds result from the oxidation of a small part of the nitrous oxide (N_2O) produced by bacteria at the surface of the earth. Nitrous oxide is inert in the troposphere so that a large fraction of the N_2O reaches the stratosphere. There, most of the N_2O is photodisassociated into molecular nitrogen (N_2) and O. The remaining N_2O yields nitric oxide, which acts as the catalytic agent.

Stratospheric chlorine is the result of gradual upward movement of chlorine-containing compounds from the troposphere. The amount of natural stratospheric chlorine is small and results from those tropospheric chlorine compounds with the most stability. Sources suspected of contributing chlorine to the stratospheric region include methyl chloride, natural carbon tetrachloride,[62] volcanic emissions, and sea salt spray.[63]

Stratospheric ozone plays two important roles in the environment of the biosphere. First, the photochemical processes in the stratosphere help filter the sunlight and thereby reduce the intensity of

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[62] Council on Environmental Quality, Fluorocarbons and the Environment: Report of Federal Task Force on Inadvertent Modification of the Stratosphere (IMOS), June 1975.

[63] National Academy of Sciences, Halocarbons: Effects of Stratospheric Ozone, Washington, D.C., 1976.

UV light that reaches the ground. Molecular oxygen is a strong absorber for wavelengths below 240 nanometers (nm). The ozone formed from atomic and molecular oxygen absorbs radiation in the wavelength range from 240-320 nm. This range of wavelengths covers that part of the ultraviolet spectrum which affects man and other organisms. Second, the presence of ozone in the stratosphere is a contributing factor in determining the climate of the earth. Because of the photochemical properties of ozone and its parents, molecular and atomic oxygen, the upper stratosphere is nearly as warm as the earth[64] and influences the radiative transfer of the atmosphere.

Ozone exhibits its highest concentrations in the atmosphere between about 12 and 50 kilometers, with the maximum occurring above 25 kilometers; the exact altitude depends on season and latitude (see Figure 5-14). The total ozone column can be conveniently defined in terms of its total burden: the number of molecules of ozone within a cylinder of unit area (usually 1 cm^2) between the surface of the earth and the top of the atmosphere. Such a method of quantifying the amount of ozone is useful because it allows a ground-based measurement of its spatial and temporal variability. By observing the intensity of solar ultraviolet radiation reaching the ground and correcting for the sun's position in the sky, such calculations of total ozone can be obtained and, indeed, form the basis for much of the historical data on ozone variation. An example of such measurements appears in Figure 5-15.

Stratospheric ozone shows temporal variability, which includes a seasonal cycle, daily variability, slow trends, and possibly cycles related to the periodicity of the sunspot cycles and other solar phenomena.[65] Figure 5-16 illustrates the considerable variation over time for total global ozone. Even higher temporal variations occur within smaller areas. The variation of ozone concentration is shown to be related to solar activity in Figures 5-17 and 5-18. The periodic effect due to sunspot cycles is clear in Figure 5-17, and the effect of a solar proton event is shown in Figure 5-18.

The Polluted Stratosphere

The mechanisms of stratospheric ozone depletion include those processes common to the unperturbed stratosphere but accelerated by

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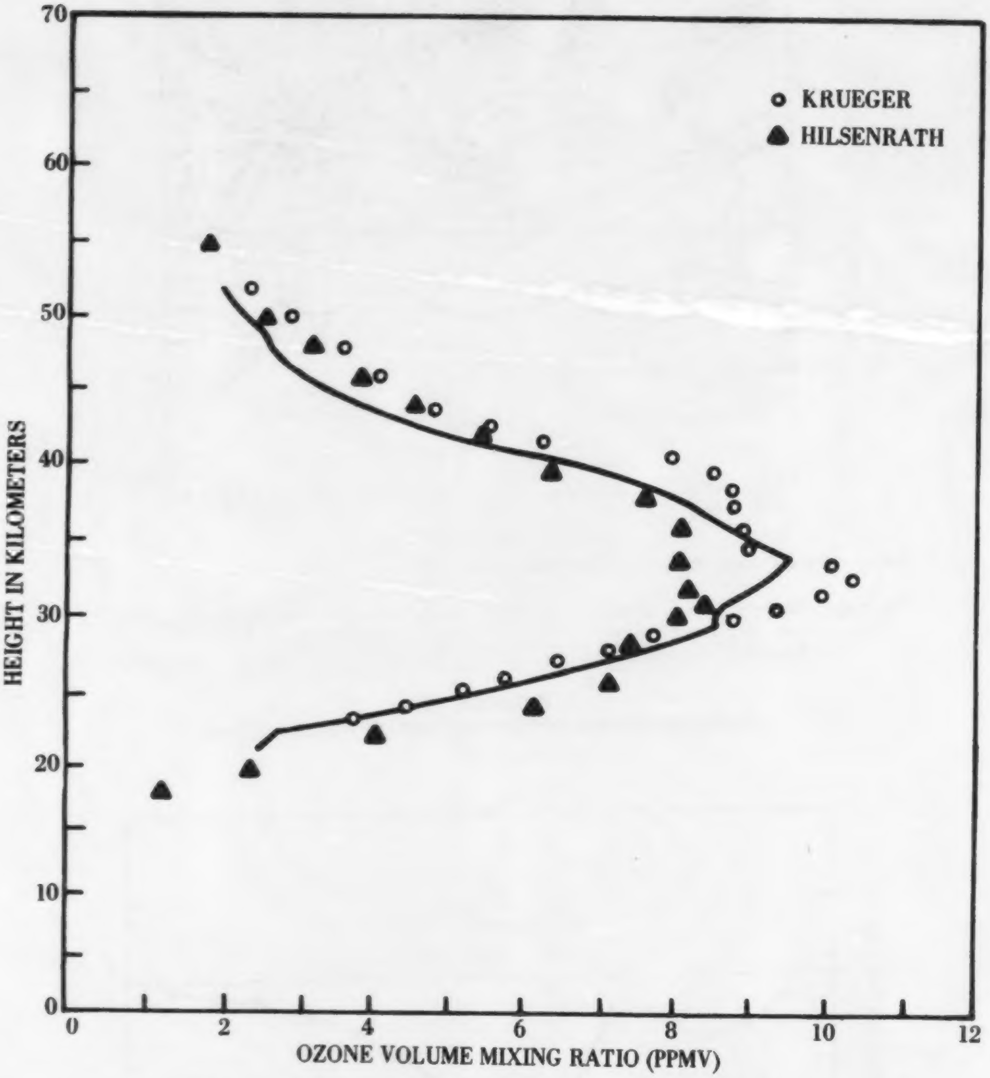
[64] Panofsky, H., "Earth's Endangered Ozone," Environment, Vol. 20, April 1979, p.17.

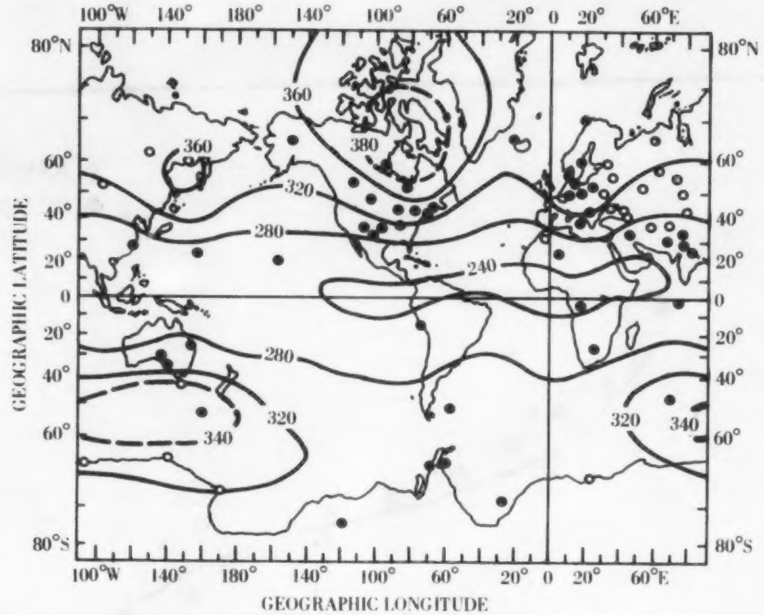
[65] Parry, H.D, "Ozone Depletion by Chlorofluoromethanes? Yet Another Look," Journal of Applied Meteorology, Vol. 16, November 1977, p. 1137. See also: "Solar Flickers Linked with Ozone Fluctuations," New Scientist, Vol. 79, August 31, 1978, p. 621.



Note: The solid line is a preliminary retrieval from measurements by the LRIR aboard the Nimbus-6 satellite, Symbols show in situ measurements from rockets by the Krueger optical ozonesonde and the Hilsenrath chemoluminescent sonde.

Source: Adapted from Hudson, R., ed., Chlorofluoromethanes and the Stratosphere, Reference publication 1010, National Aeronautics and Space Administration, Washington, D.C., August 1977.

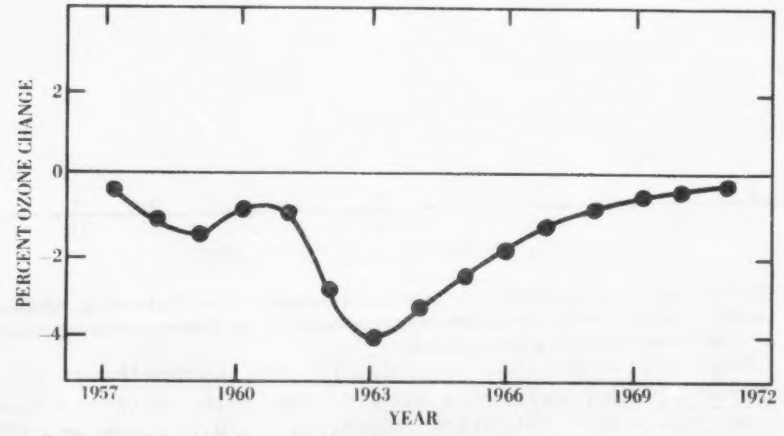
FIGURE 5-14
OZONE PROFILE IN THE STRATOSPHERE
OVER WALLOPS ISLAND, VIRGINIA
JULY 29, 1975


100°W 140° 180° 140° 100° 60° 20° 0 20° 60°E
80°N
60°
40°
20°
0
20°
40°
60°
80°S
GEOGRAPHIC LATITUDE
GEOGRAPHIC LONGITUDE
360
360
380
320
280
240
280
320
340
320
340

Note: Ozone amounts in milli-atmosphere-cm.

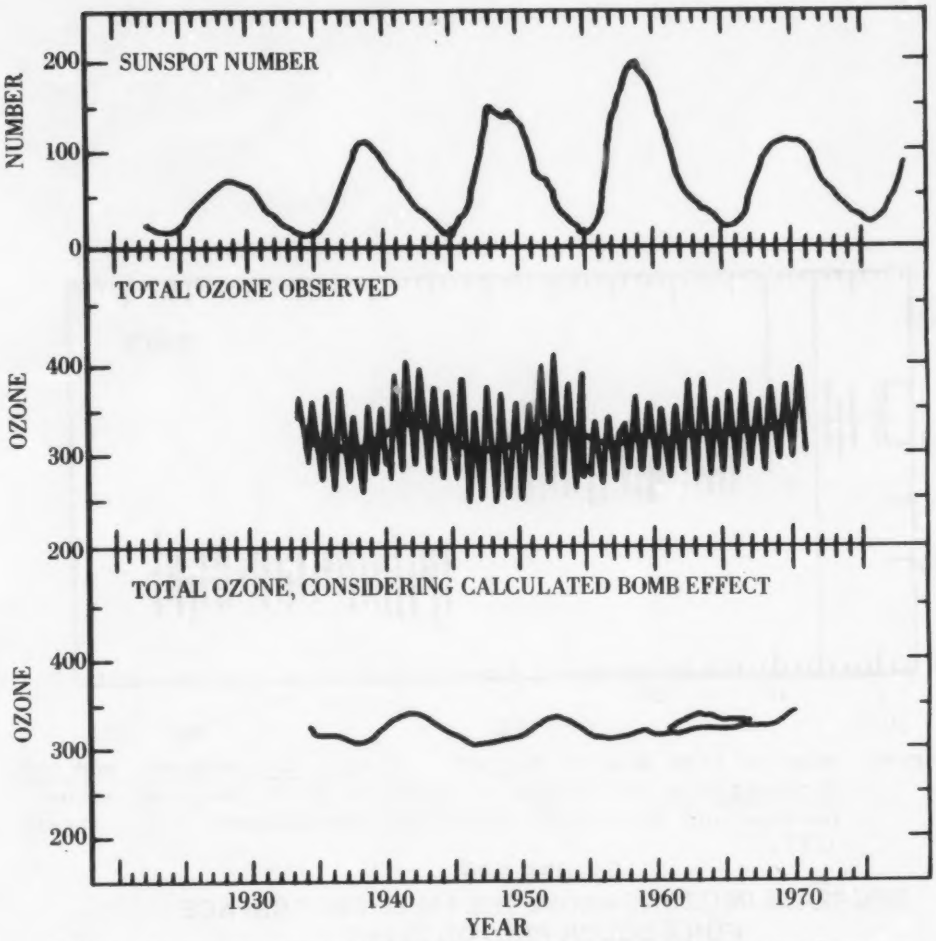
Source: Adapted from Council on Environmental Quality, Fluorocarbons and the Environment: Report of the Federal Task Force on Inadvertent Modification of the Stratosphere(IMOS), June 1975.

FIGURE 5-15
AVERAGE GLOBAL DISTRIBUTIONS OF TOTAL OZONE



Source: Adapted from National Academy of Sciences, Environmental Impact of Stratospheric Flight, Washington, D.C., 1975.

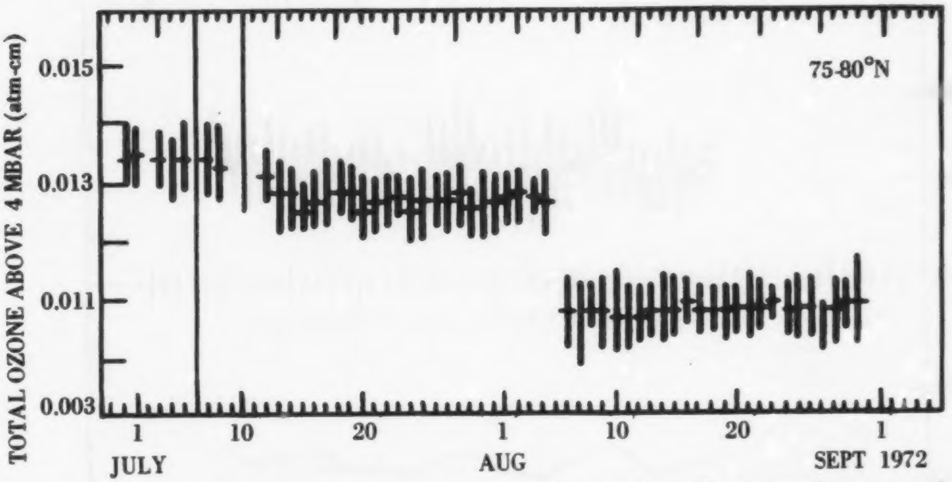
FIGURE 5-16
CHANGE OVER TIME OF WORLD OZONE



Note: Ozone concentration is in milli-atmosphere centimeters at Standard Temperature and Pressure. In the third panel, a correction for nuclear bomb effects is included, (see Figure 5-20).

Source: Adapted from National Academy of Sciences, Environmental Impact of Stratospheric Flight, Washington, D.C., 1975.

FIGURE 5-17
AVERAGE OZONE AND SUNSPOT NUMBER



Source: Adapted from Hudson, R., ed., Chlorofluoromethanes and the Stratosphere, Reference publication 1010, National Aeronautics and Space Administration, Washington, D.C., August 1977.

FIGURE 5-18
DECREASE IN OZONE ABOVE THE 4 MILLIBAR SURFACE FOR A SOLOR-PROTON EVENT AUGUST 4, 1972

the existence of higher than natural concentrations of catalytic agents. This will result in ozone levels which are smaller than would have occurred in an unpolluted environment. Furthermore, the low mixing rate characteristic of the stratosphere encourages long-term residence of these pollutants.

Most of the chlorofluorocarbons released in the lower atmosphere are in the forms of F-11 and F-12. These and other chlorofluorocarbons remaining in the troposphere are chemically inert in the troposphere.[66] The small part (approximately 1 percent per year) that reaches the stratosphere is decomposed by UV radiation, yielding free chlorine. Other sources of chlorine include man-made carbon tetrachloride, trichloroethylene, methyl chloroform, and several other chlorofluorocarbons.[67] Exhaust from launches of the space shuttle will also contribute chlorine to the stratosphere.

The production rates of chlorofluorocarbons F-11 and F-12 are shown in Table 5-4. Figure 5-19 shows the expected change in trend line resulting from the imposition of controls on release.

The lifetime of chlorofluorocarbons in the lower atmosphere is an important factor in determining the amount that might survive to affect stratospheric levels. Over a dozen possible processes for removal of chlorofluorocarbons have been studied, and only two--removal at the ocean surface and active removal in the stratosphere by photolysis--proceed at significant rates. Even these two reactions would require more than 50 years to reduce the current chlorofluorocarbon concentration to half its present value.[68] Clearly, most chlorofluorocarbon molecules, once released into the atmosphere, remain intact for many years and can serve as persistent sources of chlorine in the stratosphere.

The existence of other halogens in the stratosphere has been considered as well, since they can act in the same catalytic role as chlorine. One example is methyl bromide, which is used in large

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[66] Panofsky, H., "Earth's Endangered Ozone," Environment, Vol. 20, April 1979, p.17.

[67] National Academy of Sciences, Halocarbons: Effects on Stratospheric Ozone, Washington, D.C. 1976. See also: McConnell, J., and H. Schiff, "Methyl Chloroform: Impact on Stratospheric Ozone," Science, Vol. 199, January 13, 1978, p. 174. Comments by A. Altshuller and H. Singh and response by the authors in Science, Vol. 199, May 19, 1978.

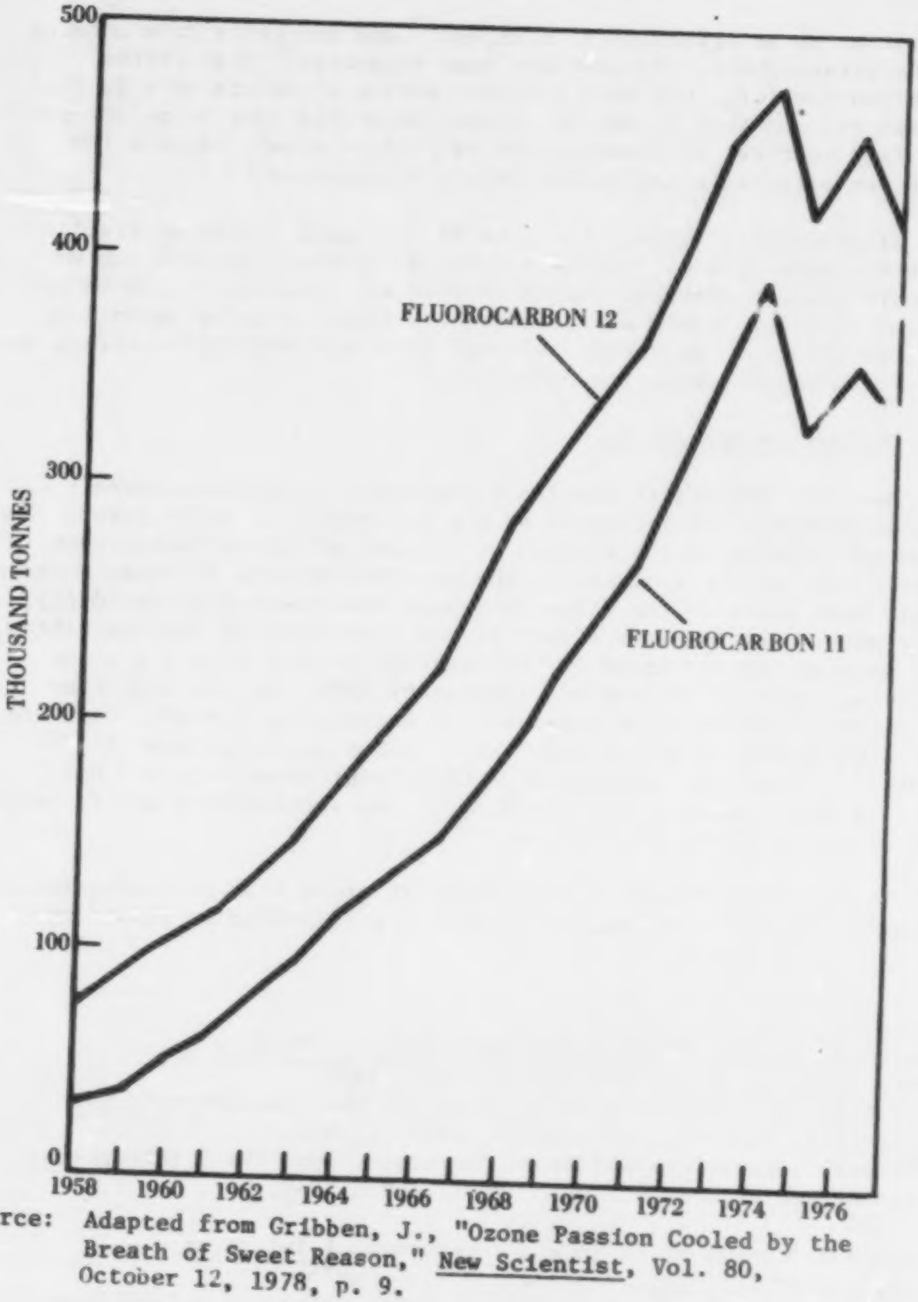
[68] Hudson, R., ed., Chlorofluoromethanes and the Stratosphere, Reference Publication 1010, National Aeronautics and Space Administration, Washington, D.C., August 1977.

TABLE 5-4
PRODUCTION OF SELECTED FLUOROCARBONS: 1958-1973
(MILLIONS OF POUNDS)

			F-11 (CCl_3F)		F-12 ($CClF_2$)	
Year	F-22[a] ($CHClF_2$)	F-114 ($CClF_2CClF_2$)	U.S.	World Total	U.S.	World Total
1958			51	51	131	131
1959			60	60	157	157
1960			72	89	166	191
1961			91	114	173	208
1962	22	11	124	158	207	258
1963	36	12	140	184	217	284
1964	43	13	148	206	228	315
1965	50	22	170	246	271	385
1966	56	17	170	268	286	432
1967	59	22[a]	182	307	310	497
1968	55	17[a]	204	364	326	565
1969	71		239	435	368	661
1970	73		244	478	375	725
1971	80		258	532	390	801
1972	80		300	628	439	931
1973			325	690	487	1,034
Totals				4,810		7,575

[a] Sales.

Source: Adapted from Council on Environmental Quality, Fluorocarbons and the Environment: Report of Federal Task Force on Inadvertent Modification of the Stratosphere (IMOS), June 1975.



Source: Adapted from Gribben, J., "Ozone Passion Cooled by the Breath of Sweet Reason," New Scientist, Vol. 80, October 12, 1978, p. 9.

FIGURE 5-19
GLOBAL FLUOROCARBON PRODUCTION

quantities as an agricultural fumigant[69] and may contribute bromine to the stratosphere. It also has been suggested[70] that carbon tetrafluoride (CF_4) may be a dominant source of halocarbons in the atmosphere, and that it may be created naturally from an as yet unidentified source. If fluorine concentrations remain below a few parts per billion, a negligible effect is expected.[71]

Stratospheric flight, in spite of the small amount of traffic above the troposphere, remains a topic of interest because engine exhausts contain nitrogen compounds that are expected to add to the natural nitrogen levels and thereby contribute to ozone depletion. But such flight is presently believed to have a negligible effect on the stratospheric ozone concentration.

Regulatory Background

American efforts to develop a supersonic transport aircraft led to concern about the integrity of the stratospheric ozone layer. The issue now centers on the effects of release of chlorofluorocarbon gases. Most of the analysis of the possible effects of stratospheric flight took place in the Climatic Impact Assessment Program (CIAP), a major multi-year research effort of the Department of Transportation. This program was initiated by the Congress in 1971 with a goal of receiving analyses of possible impacts by 1974. At the same time, the National Academies of Sciences and Engineering formed a Climatic Impact Committee to advise CIAP and to issue an independent final report.[72] Since the completion of CIAP, additional research has led to a more complete understanding of the stratosphere and the ways that aircraft affect the regions.

The possible threat to stratospheric ozone from chlorofluorocarbon gases was first recognized by Molina and Rowland in 1974[73] and was later analyzed by Crutzen[74] and Cicerone et al.[75] Various research institutions and scientists have since helped refine our understanding of this threat. Most remarkable has been the prompt response of government in addressing the chlorofluorocarbon issue. As early as 6 months after the Molina and Rowland paper, the Council on Environmental Quality and the Federal Council for Science and Technology worked together to create an Interagency Task Force on Inadvertent Modification of the Stratosphere (IMOS).[76] By June 1975, IMOS released its findings and recommendations for governmental action.

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[69] National Academy of Sciences, Halocarbons: Effects on Stratospehric Ozone, Washington, D.C., 1976.

[70] "Rich Natural Sources of Halocarbons in the Atmosphere," New Scientist, Vol. 81, February 15, 1979, p. 477.

[71] National Aeronautics and Space Administration, The Stratosphere: Present and Future, Reference Publication 1049, December 1979, p. 344.

[72] National Academy of Sciences, Environmental Impact of Stratospheric Flight, Washington, D.C., 1975.

[73] Molina, M. and F. Rowland, "Stratospheric Sink for Chlorofluoromethanes: Chlorine Atom-Catalyzed Destruction of Ozone," Nature, Vol. 249, June 28, 1974, p. 810.

Over subsequent years, regulatory action to control release of chlorofluorocarbons was taken, under provisions of the Clean Air Act, the Toxic Substances Control Act and the Federal Food, Drug, and Cosmetic Act. In addition, the 1977 Amendments to the Clean Air Act assigned EPA the responsibility for actions required to protect the ozone in the stratosphere. Chlorofluorocarbons have been banned for use as propellants (with certain exceptions) in the United States since April 1979.[77]

Because about one-half of the chlorofluorocarbons used in the United States were for aerosol propellants[78] and because the United States used half the chlorofluorocarbons produced worldwide, a ban on propellant uses in the United States reduces emissions by only approximately 20 percent.[79]

International activities designed to exchange knowledge on the impact of chlorofluorocarbons on the ozone layer have been coordinated, to a great extent, by the United Nations Environmental

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[74] Crutzen, P., "Estimates of Possible Future Ozone Reductions from Continued Use of Fluoro-Chloro-Methanes (CF_2Cl_2, $CFCL_3$)," Geophysical Research Letters, Vol. 1, September 1974, p. 205.

[75] Cicerone, R.J., R.S. Stolarksi, and S. Walters, "Stratospheric Ozone Destruction by Man-Made Chlorofluoromethanes," Science, Vol. 185, September 27, 1975, p. 1165.

[76] Council on Environmental Quality, Fluorocarbons and the Environment; Report of Federal Task Force on Inadvertent Modification of the Stratosphere (IMOS), June 1975.

[77] Brennan, R.P., "A Soft Approach to Chlorofluorocarbon Regulation," Environment, Vol. 21, April 1979, p. 41. See also: Gibbons, S., "Regulation of Chlorofluorocarbons: Phase I," Environment, Vol. 20, May 1979, p. 5.

[78] Panofsky, H., "Earth's Endangered Ozone," Environment, Vol. 20, April 1979, p. 17.

[79] Ibid.

Program.[80] Their work includes the organization of the Coordinating Committee on the Ozone Layer, which implements elements of the United Nations Environmental Program's plan of action to deal with the threat to ozone. However, some individual countries, Canada and those in Scandinavia, have taken a course of action similar to that of the United States. The Common Market nations are considering action to control aerosol emissions. Their actions are predicted to lower emissions outside the U.S. by 8 to 10 percent of the 1974 level.[81]

Two major international meetings concerned with this problem have been held. The first of these was held in Washington in 1977 at the invitation of the United States, and the second in 1978 in Munich under the sponsorship of the Federal Republic of Germany. At each meeting, the U.S. delegation presented the most recent scientific findings and argued for greater international control of this problem.[82] Typically, the problems encountered at these meetings result from the inability to translate a consensus of threat among scientists to a course of action involving regulation and possible negative economic impacts. The UNEP meetings consider only technical developments and analyses.

5.4.3 Relevant Scenario Assumptions

Estimates of ozone depletion are derived from atmospheric models which, in their most sophisticated form, include the effects of horizontal and vertical transport, as well as chemical processes. The inputs to these models include the parameters describing these various physical and chemical processes and the state of the unperturbed atmosphere. In addition, the models use assumptions concerning the magnitude of release of chlorofluorocarbons.

Early estimates of the effect of chlorofluorocarbons, for example, were based on an assumed emission rate equal to that for 1973, and they further assumed that this rate would continue until an equilibrium ozone concentration was achieved.[84] The imposition of controls on chlorofluorocarbon emissions in the United States has, of course, required a change in these assumptions. More recent estimates are derived from assumptions that the 1977 rate will continue unchanged.[85]

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[80] Gibbons, S., "Regulation of Chlorofluorocarbons: Phase I," Environment, Vol. 20, May 1979, p. 5.

[81] National Academy of Sciences, Protection Against Depletion of Stratospheric Ozone by Chlorofluorocarbons, Washington, D.C., 1979.

[82] Stoel, T., "Fluorocarbons, A Global Environmental Case Study," New Scientist, Vol. 82, January 18, 1979, p. 166.

[83] National Academy of Sciences, Environmental Impact of Stratospheric Flight, Washington, D.C., 1975.

[84] Parry, H.D., "Ozone Depletion by Chlorofluoromethanes? Yet Another Look," Journal of Applied Meteorology, Vol. 16, November 1977, p. 1137.

The inclusion of other sources of chlorine, or other halocarbons, in an ozone reduction model expands projection possibilities enormously. In one example, four different postulations for chlorofluorocarbon and methyl chloroform release were used to estimate eventual impacts on ozone.[86] Natural contributions may also be included in the model inputs and add other dimensions.

A number of different hypotheses have been employed to estimate the ozone depletion induced by stratospheric flight. Common among these are (1) the actual number of Russian and British-French SSTs; (2) 500 SSTs; and (3) 100 large SSTs, as might have been built by the United States until other forces prevented their development. As in the case of chlorofluorocarbons, models of ozone depletion resulting from these fleets of aircraft also make use of other information; for example, engine design, nitrogen emission rates, flight paths and frequency, and technological developments such as fuel cleaning are included.

5.4.4 Data Sources and Quality

Estimates of the magnitude of ozone decrease are generally acknowledged to be imprecise. The cornerstone of the calculation is an estimate of the emission rate of important pollutants, which is dominated by halogen releases in the troposphere. Anthropogenic emissions of chlorofluorocarbons are estimated to an accuracy of 5 percent.[87] The natural sources of halogens, such as methyl chloride and carbon tetrafluoride, have not been clearly identified or quantified, but estimates of their impact have been made by the National Academy of Sciences and others.

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[85] Gribben, J., "Disappearing Threat to Ozone," New Scientist, Vol. 81, February 15, 1979, p. 474. See also: Stoel, T., "Fluorocarbons, A Global Environmental Case Study," New Scientist, Vol. 82, January 18, 1979, p. 166.

[86] McConnell, J. and H. Schiff, "Methyl Chloroform: Impact on Stratospheric Ozone," Science, Vol. 199, January 13, 1978, p. 174. Comments by A. Altshuller and H. Singh and response by the authors in Science, Vol. 199, May 19, 1978.

[87] McCarthy, R., F. Bower, and J. Jesson, "The Flurocarbon-Ozone Theory-I, Production and Release--World Production and Release of CCl_3F and CCl_2F_2 (Fluorocarbons 11 and 12) through 1975," Atmospheric Environment, Vol. 11, 1977, p. 491.

In addition to estimates of the rate of release of these gases to the troposphere, subjects such as removal mechanisms, vertical transport, and chemical rate coefficients must be considered. As more information is gathered, new and improved estimates of ozone depletion can be made. Confidence in the newer estimates must be tempered, however, by the fact that even slight changes in some model inputs can result in significant changes in the predictions. For example, original estimates that stratospheric flight would reduce ozone quantities have been altered by the inclusion of new chemistry and new data; a slight increase in ozone is now predicted to result from flights in the lower stratosphere, with the possibility of a slight decrease in ozone from higher altitude flights.

5.4.5 Trends in Factors Affecting Ozone

As noted in the introduction, a number of mechanisms can reduce ozone in the stratosphere, in varying amounts. Some of these are briefly discussed below.

Chlorofluorocarbons F-11 and F-12

Emissions of chlorofluorocarbons F-11 and F-12 for propellant applications came under control as the United States took action to restrict unnecessary emissions. Among members of the European Economic Community, a control program is expected to lower chlorofluorocarbon releases to 70 percent of 1976 rates.[88,89] Because the rate of propagation of chlorofluorocarbons into the stratosphere is slow, and because these compounds have few known tropospheric sinks, the already existing tropospheric concentrations will continue to contribute chlorine to the stratosphere. Even if all tropospheric emissions were halted, it would take about 50 years[90] for removal of one-half the chlorofluorocarbons to occur.

Other Halocarbons

Sources of halocarbons other than chlorofluorocarbons F-11 and F-12 include both man-made and natural materials. Methyl

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[88] National Academy of Sciences, Protection Against Depletion of Stratospheric Ozone by Chlorofluorocarbons. Washington, D.C., 1979.

[89] Gribben, J., "Disappearing Threat to Ozone," New Scientist, Vol. 81, February 15, 1979, p. 474 and National Academy of Sciences, Protection Against Depletion of Stratospheric Ozone by Chlorofluorocarbons, Washington D.C., 1979.

[90] Panofsky, H., "Earth's Endangered Ozone," Environment, Vol. 20, April 1979, p. 17.

chloroform,[91] an inert solvent, has been identified as a significant source of stratospheric chlorine which may, depending on additions of chlorine from chlorofluorocarbons, increase the rate of ozone depletion by about 20 percent. Methyl chloride, a natural product of forest fires and other sources, has been estimated as such a significant source in the troposphere that it dominates man's contribution.[92] Carbon tetrafluoride, which is very stable in the troposphere, releases fluorine rather than chlorine in the stratosphere and is thought to have both natural and man-made sources.[93] This source of halogens in the stratosphere is also thought to be large with respect to the contribution from chlorofluorocarbons. Methyl bromide, a man-made chemical, is considered to be an additional ozone-depleting material, since it contributes bromine to the stratosphere.

Stratospheric Flight

The possibility that stratospheric flight might result in reduced ozone initiated concern about this atmospheric region. The first concern centered on the development of supersonic commercial airliners which release engine exhaust including water vapor and oxides of nitrogen; both these components might augment the natural participants in ozone depletion. Subsonic flights in polar regions might produce the same effects, since the lower altitude of the tropopause in that region puts even conventional jet airliners in the stratosphere.

Two elements have substantially reduced the projected ozone depletion that might result from such flights. First, the number of aircraft that fly in this region, particularly SSTs, has been substantially reduced by other forces, including economics and noise impact. Second, and perhaps more important, further laboratory studies and recalculation with more refined estimates of chemical rate coefficients have altered the expected impact to include the possibility that the engine emissions slightly increase ozone in the lower stratosphere.[94]

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[91] McConnell J., and H. Schiff, "Methyl Chloroform: Impact on Stratospheric Ozone," Science, Vol. 199, January 13, 1978, p. 174. Comments by A. Altshuller and H. Singh and response by the authors in Science, Vol. 199, May 19, 1978.

[92] Gribben, J., "Ozone Passion Cooled by the Breath of Sweet Reason," New Scientist, Vol. 80, October 12, 1978, p. 94.

[93] Stoel, T., "Fluorocarbons, a Global Environmental Case Study," New Scientist, Vol. 82, January 18, 1979, p. 166.

[94] Panofsky, H., "Earth's Endangered Ozone," Environment, Vol. 20, April 1979, p. 17. See also: Gribben, J., "Disappearing Threat to Ozone," New Scientist, Vol. 81, February 15, 1979, p. 474.

A mechanism which leads to reduced estimates of ozone depletion was found to relate nitrogen and chlorine compounds. The rate of the reaction:

$$ClO + NO_2 + M = ClNO_3 + M$$

(where M is some other catalyzing molecule)

has been evaluated and is found to be sufficiently fast to offer a sink for both nitrogen and chlorine (since $ClNO_3$ is relatively stable). In addition, one of the key processes in removal of NO is:

$$HO_2 + NO = OH + NO_2.$$

The rate constant for this process has been found to be greater than earlier estimates. The higher rate of production of OH means a more effective sink for nitrogen, since OH reacts with oxides of nitrogen to form nitric acid. This acid does not react with ozone and is susceptible to rainout in the troposphere. Also, the increased rate implies a lower steady-state concentration of NO, which reduces the catalytic consumption of nitrogen by ozone. Inclusion of all these factors in a model of the stratosphere leads to the prediction that flight in the lower stratosphere can be expected to slightly increase ozone concentrations, while flights at higher altitudes might produce a slight decrease in ozone.

Nitrogen Fertilizers

Nitrogen fertilizers have been used increasingly in the recent past. There is some evidence that soil processes convert some of the nitrogen to N_2O. Emission of this N_2O into the troposphere, and its eventual propagation to the stratosphere, may add to the existing stratospheric nitrogen pool and thereby add to that ozone depletion mechanism.[95] The process by which this might occur is quite complex and not well understood. The National Academy of Sciences[96] suggested in 1976 that the question of the possible impact of nitrogen fertilizers be resolved by 1981. Since that time, changes in the rate constants for the formation of $ClNO_3$ and NO_2 have resulted in a smaller perceived threat to stratospheric ozone.[97]

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[95] "Nitrate Fertilizers Threaten the Ozone Layer," New Scientist, Vol. 19, September 28, 1978, p. 918.

[96] National Academy of Sciences, Halocarbons: Effects of Stratospheric Ozone, Washington, D.C., 1976.

[97] Panofsky, H., "Earth's Endangered Ozone," Environment, Vol. 20, April 1979, p. 17.

Comparison of the threat of fertilizer with other ozone-depleting mechanisms puts this problem in perspective. Although subject to considerable uncertainty, chlorofluorocarbons are estimated to be four times as threatening, while a large fleet (500) of SSTs might be twice as dangerous to the ozone.[98] It appears that the important benefits of fertilizers to agricultural production more than offset the minor ozone depletion which might result.

Rocket Launching

The era of the space shuttle will introduce a new source of stratospheric chlorine over and above the natural sources and chlorofluorocarbons. Each launch will result in the direct injection of combustion products into the stratosphere. These include hydrochloric acid gas, solid particles of aluminum oxide, aluminum chloride, and ferric chloride. The quantities will be large (about 80 tons of HCl) and concentrated. Modeling results indicate that a program of 50 shuttle launches a year will have little effect on total ozone (reducing it by about 0.15 percent) but will concentrate its effect in the launch area. However, there will be considerable delay before 50 shuttle launches a year occur.

Other

Two other factors thought to have an effect on stratospheric ozone are solar activity[99] and nuclear detonation.[100] In the solar case, the monthly mean global ozone is found to be correlated with monthly mean solar output (as shown in Figure 5-17). Analyses of this type may be useful for isolating the relative magnitude of natural and anthropogenic impacts on stratospheric ozone.

Atmospheric detonation of nuclear weapons would introduce large quantities of nitrogen compounds into the stratosphere. A theoretical analysis of the effect is shown in Figure 5-20 for Northern Hemispheric ozone.

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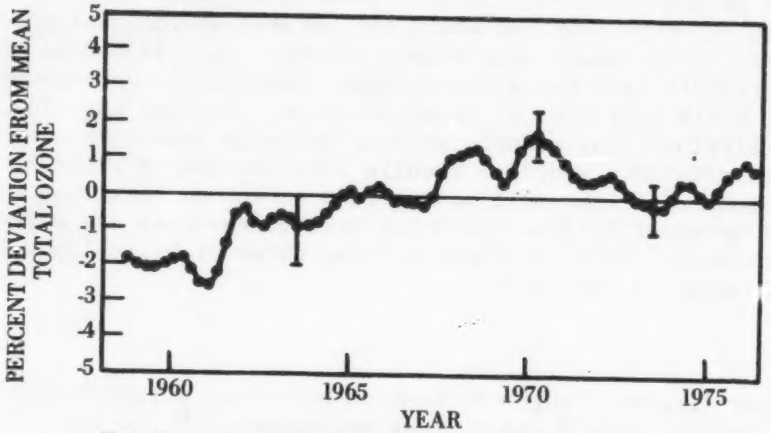
[98] "Nitrate Fertilizers Threaten the Ozone Layer," New Scientist, Vol. 19, September 28, 1978, p. 918.

[99] "Solar Flickers Linked with Ozone Fluctuations," New Scientist, Vol. 79, August 31, 1978, p. 621. See also: Keating, G., "Relation Between Monthly Variations of Global Ozone and Solar Activity," Nature, Vol. 174, August 31, 1978, p. 873.

[100] Block, B.P., "The Continuing Controversy About Ozone," Book Review of The Ozone War by L. Dotto and H. Shiff (Doubleday) in Chemical and Engineering News, July 16, 1979.



Note: Percent deviation is obtained by weighting the climatic zones by the approximate area of the Earth's surface that they represent.

Source: Adapted from Hudson, R., ed., Chlorofluoromethanes and the Stratosphere, Reference publication 1010, National Aeronautics and Space Administration, Washington, D.C., August 1977.

FIGURE 5-20
CALCULATED REDUCTION OF OZONE IN THE NORTHERN HEMISPHERE AS A RESULT OF NUCLEAR BOMB TESTS

5.4.6 Trends in Ozone Depletion

The threat of ozone depletion in the future due to a variety of human activities can be related, in principle, to past actions and the observed stratospheric ozone trends. For the most part, prediction of future ozone levels will depend on the quality of the atmospheric models used and the accuracy of inputs to the models.

Predictions

As noted earlier, prediction of ozone depletion rate is a difficult and somewhat uncertain process. Estimates are constantly modified as more is understood about the photochemical processes of the stratosphere. Early estimates assumed a continuing rate of chlorofluorocarbon release equal to the 1973 rate and calculated the ozone depletion. Normally, the depletion at equilibrium was computed: What new value of ozone concentration would exist after all atmospheric processes, including the release of chlorofluorocarbons, had come to equilibrium? A wide range of values for ozone depletion was predicted, most lying in the range of 2 to 20 percent,[101] with a 7 percent decrease suggested as quite probable.

Very recent results by the U.S. National Academy of Sciences[102] give higher estimates by concluding that release of chlorofluorocarbons at the current (1977) rate will ultimately result in a 16.5 percent decrease. Additional confirmation comes from British studies which used three different computer models but nearly the same set of supporting data. They conclude that depletions could range from 11 to 16 percent[103] with continued release at the 1975 rate. The smallest observable change in ozone is thought to be about 5-6 percent after 10 years if emission levels remain constant at the 1977 rate.

Observations

Ozone concentrations have been observed for long periods from ground-based stations in different parts of the world. More recently, satellite observations have provided synoptic maps of ozone. The World Ozone Data Center, operated by the Canadian government and the

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[101] Gribben, J., "Monitoring Halocarbons in the Atmosphere" New Scientist, Vol. 81, January 18, 1979, p. 164.

[102] National Academy of Sciences. Stratospheric Ozone Depletions by Halocarbons: Chemistry and Transport, Washington D.C., 1979.

[103] "Ozone", Sciquest 53 No. 2, February 1980, p. 26.

World Meteorological Organization, has been in existence since 1958.[104] It serves as an archive of the ground station data.

5.4.7 Impacts and Implications

The adverse effects of reduced stratospheric ozone will be global in nature. Changes in climate or in the level of ultraviolet radiation at the ground may be brought about by the activities of the rich and developed nations; those using chlorofluorocarbons, nitrogen fertilizers, or high-flying aircraft.

Human Health

The biological effects of ozone depletion center on an increased exposure of the biosphere to ultraviolet light in the wavelength range of 280-315 nm (UV-B).[105] For small changes in ozone concentration, the increase in UV-B radiation is about twice the decrease in ozone.[106] Two important health effects can be related to UV-B exposure: malignant melanoma and non-melanoma skin cancer. Malignant melanoma, a relatively rare, but 40 percent fatal skin cancer, is correlated with UV-B exposure and proximity to the equator.

Non-melanoma skin cancer is less dangerous but also shows correlation with UV-B exposure and latitude. Evidence for an increased skin cancer incidence rate as a function of UV-B exposure is shown in Figure 5-21 for both melanoma and non-melonoma. The distribution of incidence over the body is shown in Figure 5-22. The correlation of skin cancer with latitude is clearly shown in Figure 5-23. Under increased UV-B, it can be expected that higher incidence of skin cancer would occur, although the quantitative aspects of the problem are subject to some debate. The less severe phenomenon of sunburn is also expected to increase. In addition, eye damage may result, but this remains an area of continued research.[107]

Constructing a cause-and-effect relationship between ozone depletion and skin cancer will not be easy. The magnitude of the

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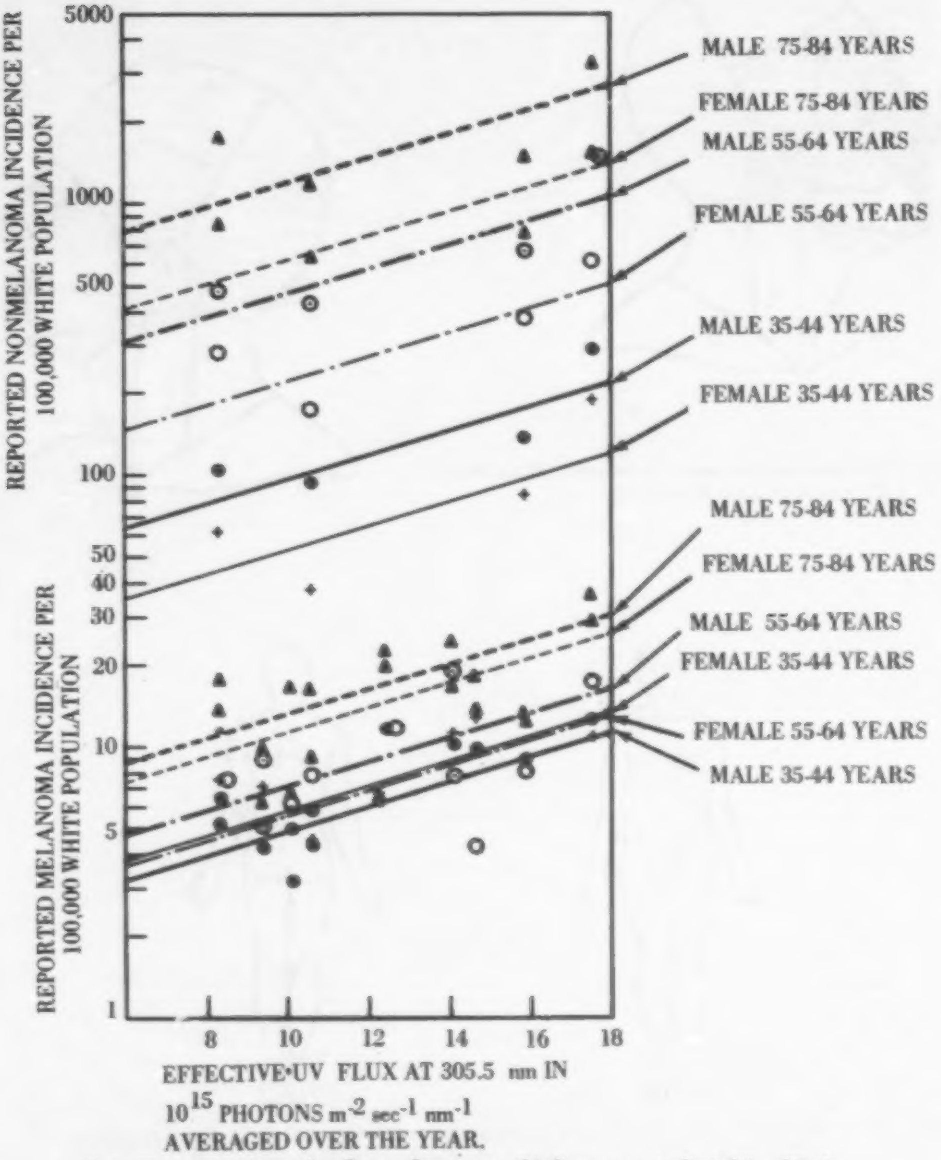
[104] Gribben, J., "Disappearing Threat to Ozone", New Scientist, Vol. 81, February 15, 1979. p. 474. Also: Parry, H.D. "Ozone Depletion by Chlorofluoromethanes? Yet Another Look," Journal of Applied Meteorology, Vol. 16, November 1977, p. 1137.

[105] Council on Environmental Quality, Fluorocarbons and the Environment; Report of Federal Task Force on Inadvertent Modification of the Stratosphere (IMOS), June 1975.

[106] Ibid.

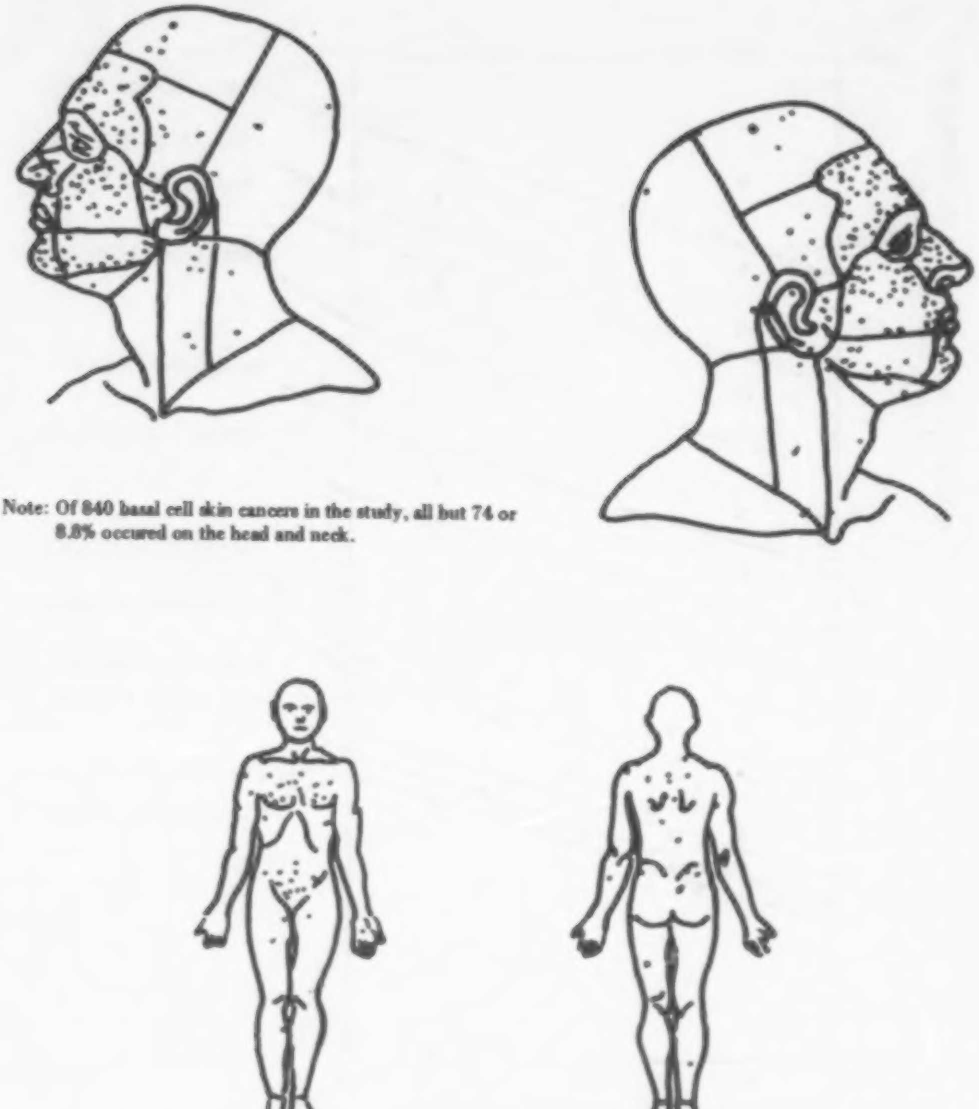
[107] Ibid.



Note: The computations of uv flux used to prepare this figure are not adjusted for altitude.

Source: Adapted from National Academy of Sciences, Environmental Impact of Stratospheric Flight, Washington, D.C., 1975.

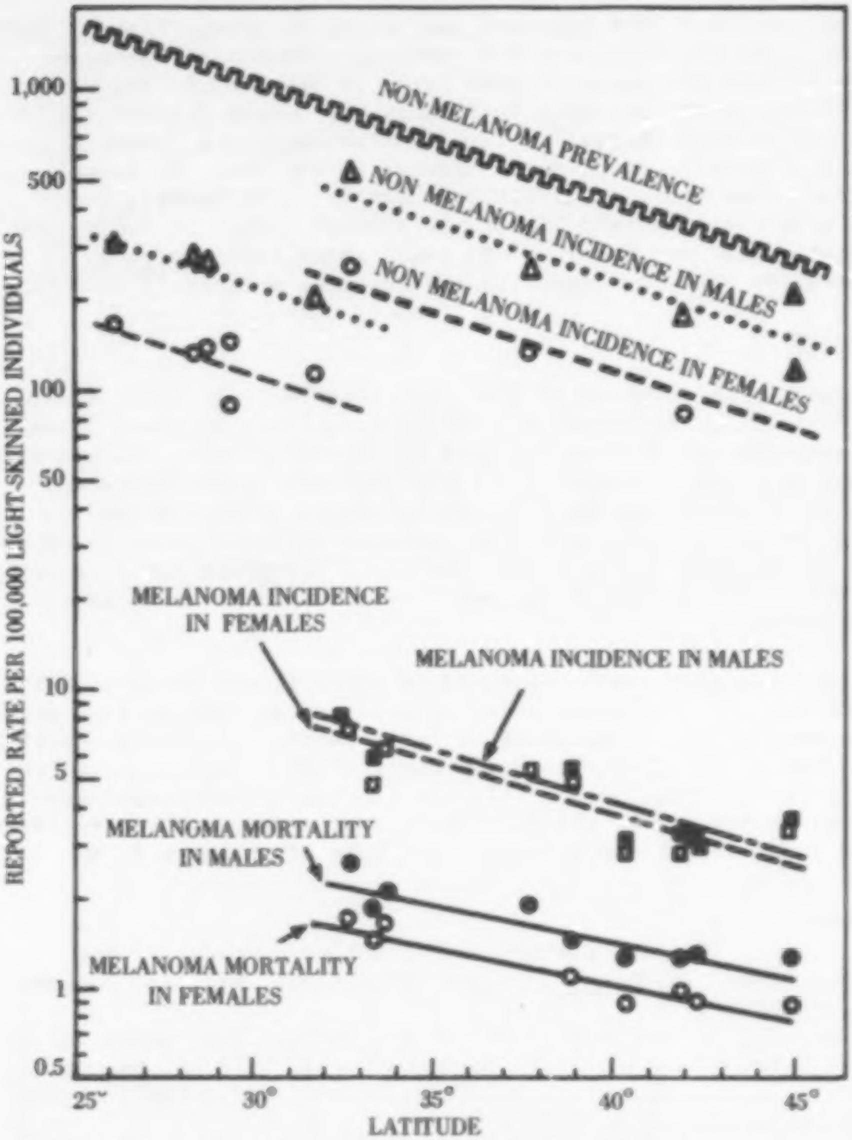
FIGURE 5-21
REPORTED SKIN CANCER RATES AMONG WHITES VS. ULTRAVIOLET FLUX



Note: Of 840 basal cell skin cancers in the study, all but 74 or 8.8% occured on the head and neck.

Source: Adapted from National Academy of Sciences, Environmental Impact of Stratospheric Flight, Washington, D.C., 1975.

FIGURE 5-22
LOCATION OF BASAL-CELL SKIN CANCERS
OF THE TORSO AND EXTREMITIES



Source: Adapted from Council on Environmental Quality, Fluorocarbons and the Environment: Report of the Federal Task Force on Inadvertent Modification of the Stratosphere (IMOS), June 1975.

FIGURE 5-23
REPORTED SKIN CANCER RATES AMONG LIGHT SKINNED INDIVIDUALS AS A FUNCTION OF LATITUDE

impact of increased UV-B exposure can be put in perspective by noting that over a period when ozone has remained constant or increased slightly,[108] the incidence of some types of skin cancer among whites living in the Northern Hemisphere has jumped dramatically--200 percent in some cases.[109] This is apparently the result of increased leisure time and more exposure to the sun. It is well known that residents of high-altitude cities, like Denver, are exposed to proportionately higher ultraviolet radiation doses than those living near sea level. Yet, skin cancer fatality rates in Denver are low when compared with the national average.[110]

Ecology

Animals other than man suffer reactions to UV-B. For example, cattle exhibit increased sensitivity to infectious diseases whose causal bacteria may be more vigorous in increased UV-B. In addition, increased UV-B could result in a small increase in cancerous eye among some breeds of cattle.[111] The incidence of disease and damage in areas of relatively high sunlight has been established and used to extrapolate to the higher losses in livestock and revenue that might result in farm areas over the globe[112] if ozone levels were to decrease.

Plant life also can be expected to react to increased UV-B in different ways.[113] Evidence exists for reactions ranging from mild to considerable. In experiments on large numbers of plants, about 20 percent showed sensitivity to daily doses of UV-B equivalent to the intensity found at the present time in Florida. A different group, also about 20 percent of all of those plants tested, showed resistance to doses four times as high. The bulk of the plants (60 percent) showed sensitivity to the intervening levels of dosage.[114] What remains to be investigated is the effect of any possible long-term exposure to sustained higher levels of UV-B radiation.

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[108] Parry, H.D., "Ozone Depletion by Chlorofluoromethanes? Yet Another Look," Journal of Applied Meteorology, Vol. 16, November 1977, p. 1137.

[109] Gribben, J., "Ozone Passion Cooled by the Breath of Sweet Reason," New Scientist, Vol. 80, October 12, 1978, p. 94.

[110] Gribben, J., "Disappearing Threat to Ozone," New Scientist, Vol. 81, February 15, 1979, p. 474.

[111] National Academy of Sciences, Protection Against Depletion of Stratospheric Ozone by Chlorofluorocarbons. Washington D.C., 1979.

[112] Council on Environmental Quality, Fluorocarbons and the Environment: Report of Federal Task Force on Inadvertent Modification of the Stratosphere (IMOS), June 1975.

[113] Ibid.

Many other aspects of life in the biosphere have been shown to be susceptible to damage from increased UV-B, such as marine organisms, algae and phytoplankton. Research is needed to study mechanisms and to assess the potential damage in these areas.

Climatic Impacts

Predicting possible climatic changes due to ozone depletion is by no means a simple task. It is suggested that ozone depletion creates changes in tropospheric climate through changes in the heating of the stratosphere and radiation scattering by chlorofluoromethane gases, aerosols and carbon doxide. Other physical mechanisms that may couple ozone reduction and climate include melting ice cover by the increased UV-B radiation and possible changes of the average global temperature.[115]

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[114] National Academy of Science, Protection Aganist Depletion of Stratospheric Ozone by Chlorofluorocarbons. Washington, D.C., 1979.

[115] Maugh, T., II and A. Hammond, "The Effects of Ozone Depletion," Science, Vol. 186, October 25, 1974, p. 337.

CHAPTER 6
WATER POLLUTANTS

HIGHLIGHTS OF CHAPTER 6

- To meet national water quality goals, recent trends in the control of point source discharges of pollutants must be sustained, and more progress must be made in the control of non-point sources.
- Industrial and municipal discharges of pollutants often are highly concentrated and localized. Non-point discharges from sources such as agriculture and urban runoff are usually greater in overall magnitude, but less concentrated.
- The effects of the various pollutants on aquatic ecosystems and water quality are recognized, but the linkages between point and non-point discharges and the occurrence of these effects are not well understood.
- Future trends in water pollution depend primarily upon the efficacy of environmental controls. Should industrial or municipal compliance with regulations lag behind schedule, the relatively favorable forecasts of point source discharges presented in this chapter would not be achieved. On the other hand, should the use of Best Management Practices become more widespread, the adverse trends in non-point discharges should be moderated.
- The identification and control of toxic substances and pesticides in water are especially important concerns because of the significant impacts caused by even small concentrations of these substances.
- While a few industries, notably steel and electric utilities, are typically identified as potential problems in terms of compliance with pollution control regulations, a number of industries are projected to accomplish substantial reductions in pollutant discharges.

6.1 INTRODUCTION

In Chapter 4, sources of air pollutants were divided into stationary and mobile sources. A similar distinction can be made for water pollutants. Point sources are those industrial plants or municipal wastewater treatment facilities that generate and discharge pollutants in their wastestreams from a pipe or other conduit. Combined sewer overflows from municipal wastewater treatment facilities, storm sewer runoff, and confined animal feedlots are classified as point sources. Non-point sources are diffuse, and include agriculture, sewered and unsewered stormwater runoff from urban areas, mining, construction, silviculture, and stream modification and natural background releases arising from land not disturbed by man's activities.[1] The distinction between point and non-point source pollution is significant; their characters are different and they pose different control problems.

Point source discharges are usually concentrated and local, and they can be controlled as the last step in an industrial process. Federal regulations consequently aim at requiring specific treatment technologies for each industry (technology-based standards). Non-point discharges, on the other hand, are more widespread and greater in overall magnitude than point source discharges. They are usually less concentrated, and can be highly variable during dry and wet weather flow periods. Even during storm events, non-point discharges can vary, since much of the pollution occurs with the first appreciable rainfall. Thus, control of non-point sources can be very difficult. They are not usually subject to effluent guidelines. EPA's approach to non-point source control is to promote sound land management practices and comprehensive land use planning.

Water quality is monitored by state water quality agencies, EPA and the U.S. Geological Survey (USGS). Other sources of information include individual state 305 (b) water quality inventory reports, individual state basin plans and 208 reports and Regional Environmental Annual Reports. Using information from individual states, EPA reported in 1978 that 95 percent of the 246 hydrological basins in the country were "affected" by water pollution.[2] A basin was said to be "affected" if a state reported that a stream segment within the basin had a problem with a pollutant that was not "minor"or insignificant."[3]

The U.S. Geological Survey's National Stream Quality Accounting Network (NASQAN)[4] has produced uniform annual water quality data since 1974. Although NASQAN data are not directly comparable with the EPA data cited above, both demonstrate the same widespread nature of water pollution problems in the United States. The results of an analysis of the changes in the NASQAN data over the 1975-1977 period are reported in Table 6-1. Despite the tentative nature of this analysis, the results indicate that there has been more improvement than deterioration with respect to zinc, fecal coliform bacteria, and dissolved oxygen, while dissolved solids, nitrogen, phosphorus, fecal streptococci bacteria, and phytoplankton (algae) showed more deterioration than improvement.[5]

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[1] U.S. Environmental Protection Agency, Methods for Identifying and Evaluating the Nature and Extent of Nonpoint Sources of Pollutants, EPA 430/9-73-014, Washington, D.C., October 1973, p. 1.

[2] U.S. Environmental Protection Agency, National Water Quality Inventory: 1977 Report to Congress, U.S. Government Printing Office, Washington, D.C., 1978. Personal communication, Alec MacBride, U.S. Environmental Protection Agency, Office of Water Planning and Standards.

[4] Ficke, J.T. and R.O. Hawkinson, The National Stream Quality Accounting Network (NASQAN) - Some Questions and Answers, Circular 719, U.S. Geological Survey, Reston, Va., 1975.

Further tests on these plus additional data from EPA's STORET data system have recently been performed by the Office of Water Planning and Standards for dissolved oxygen, phosphorus and zinc. Comparing ambient concentrations of dissolved oxygen and phosphorus on a regional basis between 1971-72 and 1977-78, they have found that dissolved oxygen levels have improved in the Northeast, Great Lakes and South, but have degraded in the West and Mid-Atlantic Regions. Phosphorus concentrations, contrary to the analysis of the NASQAN data cited above, have been found to be lower or unchanged in all monitored regions. Although results are more tentative for zinc, using data for the years 1973-74 and 1977-78, most monitoring stations have generally detected lower concentrations of this metal in the later time period.

This chapter addresses trends in water quality associated with the discharge of selected pollutants to surface waters from point sources and then, selected non-point sources. Section 6.4 discusses overall implications of both point and selected non-point source pollution trends for future water quality. A major limitation of this chapter is the incomplete coverage of toxic substances as they affect water quality. This incompleteness stems from a lack of data to base projections on. Changes in the physical characteristics of stream ecosystems, which can destroy aquatic habitats no matter how good water quality is, and which result from land use activities (such as agriculture, silviculture, mining, and construction), are also not presented in this chapter. The Office of Research and Development is funding research in this important area.

Throughout this chapter, emphasis has been placed on trends in pollutant discharges and water quality. Specific estimates of discharge quantities should be regarded as approximations rather than predictions since we are aware that most of them are subject to systematic under or overestimation (as discussed in each subsection).

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[5] Council on Environmental Quality, Environmental Quality: The Ninth Annual Report of the Council on Environmental Quality, U.S. Government Printing Office, Washington, D.C., 1978, pp. 96, 98.

TABLE 6-1
WATER QUALITY CHANGES[a] AT NASQAN STATIONS
1975 to 1977

Water Quality Characteristics	Percent of Stations		
	Improved	No Change	Deteriorated
Fecal Coliform Bacteria	7	89	4
Inorganic Nitrogen	6	87	8
Organic Nitrogen	4	83	13
Total Phosphorus	4	83	13
Dissolved Oxygen	6	93	3
Fecal Streptococci Bacteria	2	87	11
Dissolved Solids	4	74	22
Dissolved Zinc	9	87	4
Total Zinc	13	86	1
Phytoplankton	2	94	4

[a] Indications of change tested for statistical significance at the 90 percent level.

NASQAN = National Stream Quality Accounting Network, U.S. Geological Survey.

SOURCE: Council on Environmental Quality, Environmental Quality: The Ninth Annual Report of the Council on Environmental Quality, U.S. Government Printing Office, Washington, D.C., 1978, p. 96.

Despite this, we are confident of the direction and general magnitude of the trends described, and suggest that these are most important in any case. Planned improvement of the data base used to develop these projections is expected to reduce the uncertainty attached to estimates of pollutant quantity during the next several years.

6.2 POINT SOURCE POLLUTANTS

HIGHLIGHTS OF SECTION 6.2

- Point source discharges of pollutants affect 90 percent of the drainage basins in the United States.
- "Conventional" pollutants--biochemical oxygen demand, suspended solids, fecal coliform bacteria, and pH--are controlled by industry-specific treatment regulations. A reasonable level of control of these pollutants will be achieved if there is a high degree of compliance with the regulations.
- Discharges of toxic and certain other pollutants from point sources are subject to more stringent standards. Projected trends in abatement of these substances are even more favorable than for conventional pollutants, assuming compliance is achieved.
- Discharges of dissolved solids and nitrogen are projected to increase between 1975 and 2000.
- Several anticipated process changes by industry are expected to cause reductions in discharges.
- Regions with the greatest increases in population and economic output are projected to have the greatest increases in the generation of pollutants and may therefore face the most difficult control problems. This is most marked in the Southeast and South Central Regions (Federal Regions IV and VI).

6.2.1 Introduction

Problem Definition and Regulatory Background

Recent statistics show that over 90 percent of EPA-designated hydrological drainage basins in the United States are affected by point source discharges, although the nature and degree of impacts vary considerably across the country.[6] For example, the extent of water quality problems associated with industrial discharges is illustrated in Figure 6-1. These problems are most severe in the Northeast and Great Lakes areas of the country where heavy industry is centered. There, almost 90 percent of the drainage basins are affected by industrial discharges. In contrast, about a quarter of the basins in the Southwest are affected. Water quality problems resulting from municipal wastewater discharges occur most often in more heavily populated areas, but affect sparsely settled areas as well. As a result, pollution from municipal treatment plants affects almost 90 percent of the nation's drainage basins across the country. The point source water pollution problems experienced in each geographical region are summarized in Table 6-2.

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[6] U.S. Environmental Protection Agency, National Water Quality Inventory: 1977 Report to Congress, EPA 440/4-78-001, U.S. Government Printing Office, Washington, D.C., October 1978.

Control of point source discharges was mandated by Congress through the Federal Water Pollution Control Act Amendments (FWPCA) of 1972 and the Clean Water Act of 1977.[7] The FWPCA, which set the objective of eliminating discharges of pollutants into the nation's waters by 1985, required that all point source discharges meet effluent standards based on specific treatment techniques. Industrial dischargers were to adopt "best practicable control technology currently available" (BPT) by July 1, 1977, and "best available technology economically achievable" (BAT) by July 1, 1983. Municipal dischargers were required to apply secondary treatment to sewage by July 1, 1977, and "best practicable waste treatment technology" (BPWTT) by 1983. These technology-based standards were to apply regardless of receiving water quality unless they were not stringent enough to meet EPA approved state water quality standards. If the latter condition prevailed, the Federal Water Pollution Control Act Amendments of 1965[8] require the imposition of more stringent effluent controls upon point sources discharging to those waters.

The Clean Water Act of 1977 contained a number of compromises on controlling industrial discharges and extended compliance deadlines. BAT standards for "conventional pollutants" (four are defined) were superceded by "best conventional pollution control technology" (BCT) requirements, which Congress intended to be no less stringent than BPT and no more stringent than BAT requirements. For other than conventional pollutants, BAT was to be implemented within three years from the date when limitations were established by the Agency, or by July 1, 1984, whichever was later, but in no case later than July 1, 1987. For these pollutants, a discharger could be allowed a variance or modification of BAT standards, if the discharger demonstrated that

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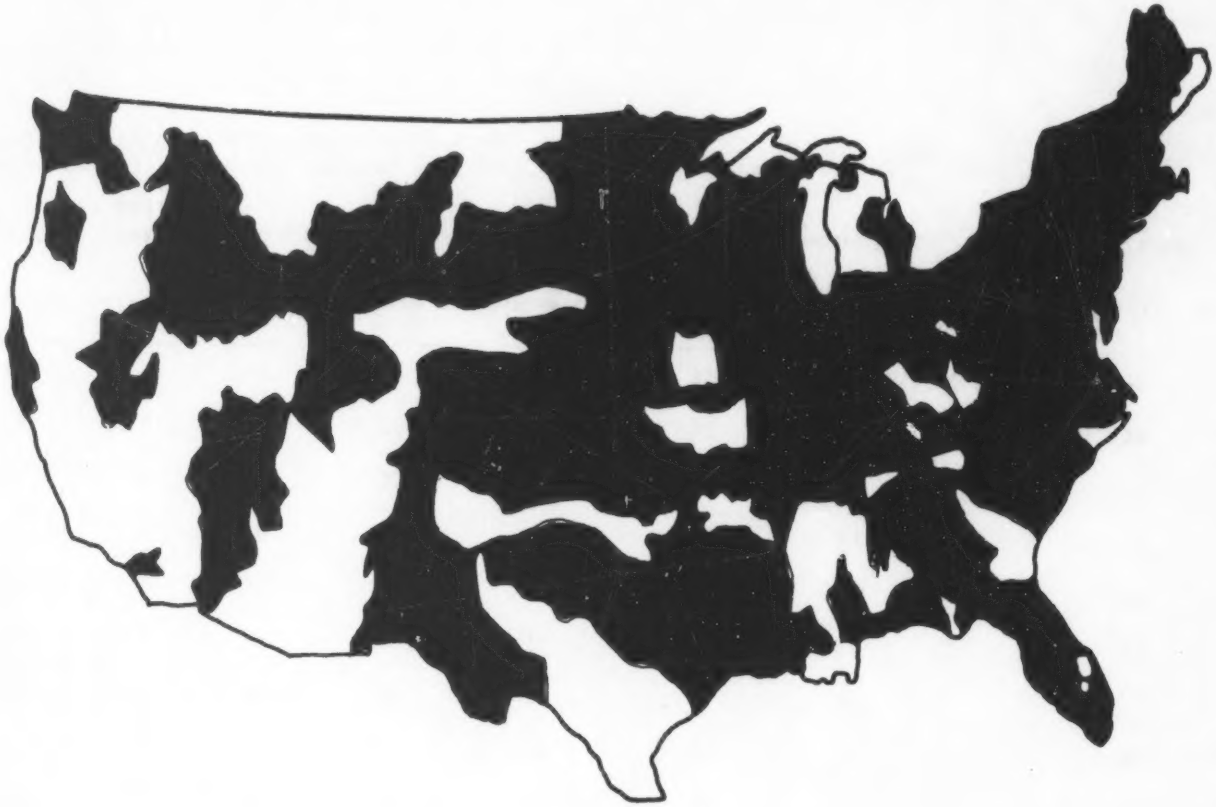
[7] Clean Water Act of 1977, 33 USC 1252 et seq. (1978 Suppl.).

[8] Federal Water Pollution Control Act Amendments of 1965, 33 USC 1151 et seq. (1978 Suppl.).



NOTE: Basins where some (or all) stream segments have a problem with pollution from industrial sources that is not minor or insignificant, according to state officials. Affected basins are shaded.

Source: U.S. Environmental Protection Agency, National Water Quality Inventory: 1977 Report to Congress, EPA 440/4-78-001, U.S. Government Printing Office, Washington, D.C., October 1978, p. 10.

FIGURE 6-1
EPA-DESIGNATED HYDROLOGICAL DRAINAGE BASINS
AFFECTED BY INDUSTRIAL DISCHARGES
1977

TABLE 6-2
WATER POLLUTION IMPACTS FROM POINT SOURCES
1977

Geographical Region[b]	Number of Basins	Percent of Basins Affected[a] by Pollution from Point Sources									
		Thermal	Bacteria	Oxygen Depletion	Nutrients	Suspended Solids	Dissolved Solids	pH	Oil and Grease	Heavy Metals	Nonmetal Toxics
Northeast	40	33	93	93	78	70	13	15	35	58	43
Southeast	47	11	77	89	70	26	9	17	6	36	28
Great Lakes	41	24	80	85	71	44	27	24	34	51	59
North Central	35	11	89	80	74	23	20	14	0	57	23
South Central	30	3	73	87	83	30	30	10	13	43	7
Southwest	22	5	50	36	41	14	23	5	5	9	5
Northwest	22	0	68	55	55	23	5	5	0	5	14
Islands	9	33	89	78	56	33	11	0	44	22	11
Total	246	15	78	79	69	35	17	14	16	38	28

[a] Basins where some (or all) stream segments have a problem that is not minor or insignificant, according to state officials.

[b] Note that the regional drainage basin groupings used here do not comform precisely to the 10 Federal Regions used in the discharge trends analvsis.

SOURCE: U.S. Environmental Protection Agency, National Water Quality Inventory: 1977 Report to Congress, EPA 440/4-78-001, U.S. Government Printing Office, Washington, D.C., October 1978, p. 11.

no adverse water quality effects would result. The Clean Water Act also authorized EPA to extend compliance deadlines for municipal sewage facilities, on a discretionary basis, up to July 1, 1983.

The four "conventional" water pollutants (to which BCT standards apply) defined by the Act are biochemical oxygen demand (BOD), total suspended solids, fecal coliform bacteria, and pH. EPA has since proposed that chemical oxygen demand (COD), phosphorus, and oil and grease be classified as conventional pollutants.[9]

Compliance with revised Federal pollution control regulations is expected to significantly reduce pollution by the mid-1980s. However, municipal dischargers are still expected to release substantial levels of pollutants in many areas even after best practicable waste treatment technology (BPWTT) is implemented. A discussion of the implications for solid waste generation from municipal and industrial sources by more complete treatment of wastewaters occurs in Chapter 10. Non-point sources are expected to grow in relative significance during the same period. Expected trends in non-point source water pollution and their implications for water quality are discussed in Section 6.3 of this chapter.

Recently, EPA has started to focus its attention upon toxic pollutants. Heightened awareness of toxic chemical problems is reflected in the 1977 Clean Water Act, which requires BAT standards by 1984 for 65 named classes of toxic chemicals.[10] Because the problems associated with toxic pollutants have only recently attracted attention, there is a considerable void in the literature, and, as a result, developing reliable data on present and future discharges of toxic pollutants is extremely difficult. Although the seriousness of toxic water pollution is recognized, a discussion of those pollutants is not included in the major section of this chapter because of the incomplete data. Instead, a less comprehensive analysis of toxic pollutants is undertaken in Section 6.2.8.

National and regional trends in the quantities of water pollutants generated and the quantities discharged are presented for point sources in terms of "gross generation" and "net discharge." The term gross generation refers to the pollutants produced by point sources and present in the untreated wastewaters of industrial plants and the untreated influent to sewage treatment plants. The term net discharge refers to the pollutants in effluent even after full treatment to the standards required by law. (For non-point sources, where pollutants are not given specific wastewater treatment by methods like those used for point sources, the distinction between generation and discharges often does not apply.)

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[9] "Identification of Conventional Pollutants," Final action, Federal Register, Vol. 44, No. 147, July 30, 1979, p. 44501.

[10] Council on Environmental Quality, Environmental Quality: The Ninth Annual Report of the Council on Environmental Quality, U.S. Government Printing Office, Washington, D.C., 1978, pp. 96, 98.

Although some degree of treatment is expected for all the pollutants identified in the following sections, it is unlikely that full treatment will be reached for any one of them. As a result, the levels of generation and discharge of pollutants should be read with caution. The corresponding values for the two parameters are intended as a range within which levels of discharges will fall according to the actual degree of attainment with BCT or BAT standards. This, however, is not factored into scenario projections. Nor do projections account for likely regional and sectional variations in compliance schedules because of capital stock or manufacturing process differences, economic, environmental or physical background conditions, locally mandated water quality limitations which are more strict than national standards, or other contingencies which affect discharge levels.

In order to assess the reliability of the SEAS estimates of water pollutants, a comparison was made between SEAS and data developed by the National Accounting and Environment (NAE) project[11] and the Draft 1977 Cost of Clean Water report.[12] These comparisons indicate that total water pollution discharges (aggregated over all point sources) for each criteria pollutant are likely to be underestimated because not all industries are covered in SEAS, and because there may be underestimates in covered industries.

Relevant Scenario Assumptions

Point source pollution is usually associated with heavy industries such as steel, chemicals, pulp and paper, and food processing, and with municipal sewage treatment. Electric utilities are also significant dischargers of some conventional pollutants. Water quality projections are therefore influenced by the population and economic growth assumptions that define the High and Low Growth Scenarios.

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[11] Gianessi, L.D. and H.M. Peskin, A Comparison of Recent National Estimates, Discussion Paper D/2, Resources for the Future, Washington, D.C., February 1977.

[12] Battelle Columbus Laboratories, Draft 1977 Cost of Clean Water, U.S. Environmental Protection Agency, Washington, D.C., 1977.

Projections of economic output by the major industrial sources of water pollution are shown in Table 6-3. Industrial expansion is expected in both scenarios, particularly in the organic chemicals and aluminum industries. Population growth is also expected, and would increase the amount of sewage to be treated by municipal facilities. This latter trend is reinforced in both scenarios through greater centralization of sewage treatment facilities. The increasing percentage of the population served by municipal facilities over the 1975 to 2000 period is shown in Table 6-4. Although greater centralization of sewage treatment increases discharges from point sources, it would reduce water quality problems associated with individual disposal systems.[13] The net effects of these trends are uncertain, because discharges from individual systems are not projected by SEAS.

The economic expansion indicated in Table 6-3 would slow after 1985. With the exception of meat products processing, the average annual growth rates of output for these industries for the 1975 to 1985 period exceed the growth rates for the 1985 to 2000 period. Thus initial compliance with guidelines would be achieved during a period of relatively rapid industrial growth.

Process changes expected in the production of steel and pulp and paper affect the environmental projections significantly. The major process change assumed in the pulp and paper industry is from the production of bleached kraft pulp to unbleached kraft, which will reduce discharges of oxygen-demanding material. We have assumed that open-hearth furnaces will be phased out by the steel industry by 2000. This production is expected to be supplanted by basic oxygen furnaces (BOF) and electric arc furnaces. Furthermore, by 2000, 5 percent of domestic steel production is anticipated to be from direct reduction methods (see Table 6-5).

These process changes are important because wastewater characteristics associated with each process vary. Greater production of steel using "cleaner" technologies can be expected to reduce the quantity of dissolved and suspended solids in the raw wastestreams of steelmaking facilities.

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[13] U.S. Environmental Protection Agency, National Water Quality Inventory: 1977 Report to Congress, U.S. Government Printing Office, Washington, D.C., October 1978, p. 22.

TABLE 6-3
PROJECTED OUTPUT AND GROWTH RATES FOR MAJOR POINT SOURCES OF WATER POLLUTION 1975, 1985, 2000
(BILLIONS OF 1971 DOLLARS UNLESS NOTED)

		High Growth Scenario				Low Growth Scenario			
				Average Annual Growth Rate (Percent)				Average Annual Growth Rate (Percent)	
Source	1975	1985	2000	1975-85	1985-2000	1985	2000	1975-85	1985-2000
Aluminum	$ 8.1	$14.8	$28.5	6.2	4.5	$13.6	$25.2	5.3	4.2
Asphalt	2.0	3.6	5.0	6.1	2.3	3.3	4.4	5.4	1.9
Electric Utilities	35.0	60.7	89.3	5.6	2.6	56.8	83.3	5.0	2.6
Meat Processing	32.5	35.3	45.3	0.8	2.5	33.4	40.1	0.3	1.8
Pulp and Paper	18.5	31.7	47.0	5.5	2.7	28.0	37.9	4.3	2.0
Steel	33.5	44.4	50.8	2.9	0.9	41.9	45.9	2.3	0.9
Textiles	32.8	54.2	85.9	5.2	5.0	43.1	60.0	2.8	2.2
Inorganic Chemicals[a]	160	250	380	4.5	7.0	220	320	3.3	6.4
Organic Chemicals[a]	60	110	190	6.9	3.5	100	150	5.6	2.9
Municipal Sewage[b]	160	190	230	1.6	1.4	180	220	1.3	1.1

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[a] In millions of tons.

[b] In millions of population served.

TABLE 6-4
U.S. POPULATION AND POPULATION SERVED BY MUNICIPAL TREATMENT FACILITIES
1975, 1985, 2000
(MILLIONS)

		High Growth		Low Growth	
	1975	1985	2000	1985	2000
Population	213	234	262	228	245
Population Served by Municipal Wastewater Treatment Facilities	161	188	232	184	217
Percentage of Population Served	75	81	88	81	88

TABLE 6-5
TRENDS IN STEELMAKING TECHNOLOGIES
(PERCENT)

	Technology			
Production Share	Open Hearth	Basic Oxygen	Electric Arc	Size Reduction
In 1975	24	57	20	--
In 1985				
High Growth	9	66	25	--
Low Growth	6	65	29	--
In 2000				
High Growth	--	68	27	5
Low Growth	--	62	38	--

Projections analyzed in this chapter depend upon assumptions concerning compliance with effluent standards by industrial and municipal sources. They are based on the compliance deadlines provided in the FWPCA Amendments of 1972, and do not incorporate the changes to standards and deadlines approved in the Clean Water Act of 1977. All industrial point source dischargers are assumed to have met BPT standards, and all municipal dischargers are assumed to have applied secondary treatment to sewage, by the mandated 1977 deadline. However, the imposition of BAT standards on industrial effluents is assumed in projections to lag two years behind the 1983 deadline set in the 1972 Act. Industrial point sources are therefore assumed to comply with BAT standards by 1985.

Projections discussed in this chapter are susceptible to error if compliance schedules change or if final BCT limitations deviate from estimated BAT standards. Delays in compliance by industrial and municipal sources would mean that projected discharges in the 1985 benchmark year are underestimated.

EPA monitoring activities found that 14 percent of major industrial dischargers did not achieve BPT, and 66 percent of municipal treatment facilities did not apply secondary treatment to sewage, by the mandated deadline of July 1, 1977.[14] Although interim and/or final guidelines for BCT (conventional pollutants) and BAT (toxic pollutants) are still scheduled to conform to dates mandated in the 1977 Act, litigation or economic impact analyses could delay implementation or enforcement of standards. The likelihood of such delays, however, cannot be established. SEAS assumptions about industrial and municipal compliance should be considered optimistic, and since BCT standards will fall within the range of BPT and BAT, SEAS projections of the amount of pollutant removed (based on BAT) should also be considered optimistic. On the other hand, the application of water quality-based standards in some areas may cause SEAS projections of pollutant removal to be overstated.

In summary, assumptions concerning compliance with effluent limitations guidelines used in the scenario projections do not incorporate changes decreed in the Clean Water Act of 1977. Given potential delays in compliance and redefinition of standards, SEAS discharge projections must be considered uncertain and are probably optimistic. Awareness of this potential bias should be maintained throughout the following water pollution analyses.

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[14] Council on Environmental Quality. Environmental Quality -- 1977. U.S. Government Printing Office, Washington, D.C., December, 1977, p. 36.

Data Sources and Quality

The analysis of point source water pollution discharges in this chapter is based upon data derived primarily from EPA Development Documents for Proposed Effluent Limitations Guidelines.[15] These data are supplemented, where necessary, by industry reports prepared for the National Commission on Water Quality as part of its study of the costs and capabilities of water pollution abatement technologies,[16] the Costs of Clean Water reports prepared for EPA,[17] and studies conducted by private industry. In addition, water pollution discharge data for municipal sewage treatment plants are derived from the 1976 EPA Needs Survey.[18]

A comparison of SEAS 1975 estimates with data developed by the NAE Project[19] and the Draft 1977 Cost of Clean Water report[20] showed that not all industrial categories that discharge significant quantities of conventional water pollutants are considered in SEAS. For example, for 56 industrial categories in the NAE database that were consistent with SEAS sector definitions, and for four of the pollutants considered in this chapter, 30 percent of all dischargers classified by NAE were not considered by SEAS (Table 6-6). Even where the same industries were considered, NAE-estimated discharges are as much as 12 times SEAS estimates for certain pollutants.

These findings should be interpreted with some caution. The NAE project was somewhat inconsistent in its estimation methods; in some

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[15] U.S. Environmental Protection Agency, Development Document for Effluent Limitations Guidelines and New Source Performance Standards, Series 440, U.S. Government Printing Office, Washington, D.C.

[16] See, for example, Lee, W.L., R.A. Leone, and C. Smith, The Economic Impact of the Federal Water Pollution Control Act Amendments of 1972 on the Nonferrous Metals Industry, National Bureau of Economic Research, Inc., New York, June 15, 1978.

[17] U.S. Environmental Protection Agency, Economics of Clean Water, 1972, Washington, D.C., 1972.

[18] U.S. Environmental Protection Agency, Office of Water Program Operations, 1976 Needs Survey: Cost Estimates for Construction of Publicly-Owned Wastewater Treatment Facilities, Washington, D.C., February 1977.

[19] Gianessi, L.D. and H.M. Peskin, A Comparison of Recent National Estimates, Discussion Paper D-2, Resources for the Future, Washington, D.C., February 1977.

[20] Battelle Columbus Laboratories, Draft 1977 Cost of Clean Water, U.S. Environmental Protection Agency, Washington, D.C., 1977.

TABLE 6-6
COMPARISON OF INDUSTRY COVERAGE BETWEEN COMPATIBLE INDUSTRIES IN SEAS AND NAE DATA BASES, BY POLLUTANT

Pollutants	(1) Number of Industries Where SEAS Has Nonzero Estimate	(2) Number of Industries Where NAE Estimate is Nonzero or Nonneglible	(3) Percent of Industries Unaccounted for by SEAS (2 - 1) ÷ (2)
Biochemical Oxygen Demand	31	45	31
Suspended Solids	34	56	30
Oil and Grease	22	26	31[a]
Dissolved Solids	29	56	48

NAE = National Accounting and Environment Project

[a] Percent of industries where SEAS or NAE has nonzero estimate (32).

industries industry-wide data were gathered, while in others only data for specific plants were considered. Also, the base year used in the NAE analysis predates the 1975 base year of SEAS by three years. Thus, discharge estimates by industrial category might differ to some extent between SEAS and NAE because the more recent data in SEAS reflect at least partial compliance with BPT standards by industry and secondary treatment of sewage by municipalities, and because of different levels of output in the two years.

In general, the comparison between SEAS and the NAE project data suggests that total water pollution discharges (aggregated over all point sources) for each criteria pollutant are likely to be underestimated to some degree because of industrial undercoverage in SEAS and, possibly, underestimates in covered industries.

Organization of Discussion

The following section presents projected national and regional trends for six water pollutants: biochemical oxygen demand, suspended solids, dissolved solids, nitrogen, phosphorus, and oil and grease. These pollutants are analyzed because they are considered to be basic water quality indicators, because they are among the largest contributors to water quality problems, and because projections of these pollutants are based upon the most reliable water pollution data currently in SEAS. Toxic pollutants receive separate treatment in Section 6.2.8 and in Chapter 11.

For each water pollutant, national trends in the quantities generated by productive and consumptive activities classified as point sources, and the quantities then discharged to surface waters after wastewater treatment, are discussed. Pollutants "generated" by point sources are those which exist in wastewaters before being subject to treatment, and their introduction into wastestreams is referred to throughout the section as "gross generation." Pollutants that would be discharged in effluents even after full treatment to the standards required by law are referred to as "net discharges." There is often a wide difference between "gross generation" and "net discharge" estimates for a pollutant, which will not be realized unless full compliance occurs. To provide a better indication of the amount of pollutants reaching natural streams, the concept of "intermediate discharges" has been used. This is the level of pollutants in effluent after treatment, if removal efficiencies were to remain at their 1975 levels.[21]

Following the discussions of the six pollutants defined above, selected toxic and non-toxic pollutants are analyzed. Alternative data sources have been used for this, since reliable projections are not available in SEAS. A summary section for point source water pollution projections concludes this part of the chapter.

6.2.2 Biochemical Oxygen Demand

HIGHLIGHTS OF SECTION 6.2.2

- Municipal treatment plants are the major sources of BOD. In 1975, it is estimated that municipal plants accounted for 53 percent of all point discharges of BOD. This proportion is expected to increase to 85 percent by 2000.
- The pulp and paper industry and, to a lesser extent, the meat processing, organic chemicals, sugar, and fruit and vegetable processing industries are other sources of BOD discharges.
- The gross generation of BOD is expected to increase in all regions, with the Southeast, Great Lakes, and South Central Regions (Federal Regions IV, V, and VI) experiencing the greatest increases.
- BOD discharges following treatment are expected to decline in all regions.

Introduction

Biochemical oxygen demand (BOD) is a measure of oxygen-demanding matter in water. Materials which may contribute to BOD include carbonaceous organic materials usable as a food source by aerobic organisms; oxidizable nitrogen derived from nitrites, ammonia and organic nitrogen compounds that serve as food for specific bacteria;

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[21] This approach will result in some overestimation of discharges released by point sources, since there is a pronounced trend toward compliance by major industries. In July 1977, 30 percent of major facilities with NPDES permits were in violation of guidelines, but this declined to 14 percent as of June 1979. The "intermediate discharges" are not meant to be a prediction of actual discharge levels, but rather are presented as probable upper bounds to discharge levels in effluent, just as "net discharges" are likely lower bounds.

and certain other oxidizable materials such as ferrous iron, sulfides, and sulfite, which react with dissolved oxygen or are metabolized by bacteria.

The biochemical oxygen demand of wastewater exerts an adverse effect upon the dissolved oxygen resources of a body of water by reducing the oxygen available to fish, plant life, and other aquatic organisms. The manner in which organic materials present in water are decomposed in the absence of sufficient dissolved oxygen leads to the formation of noxious gases, such as hydrogen sulfide, which in turn causes sludge beds to float. This can degrade the aesthetic quality of the water body and reduce its usefulness for recreation.

Insufficient dissolved oxygen in drinking water supplies may adversely affect water taste by promoting the chemical reduction and subsequent leaching of iron and manganese from sediments.[22] Removal of these metals during water treatment imposes additional cost upon municipalities.[23]

BOD Discharge Trends

BOD is reported as 5-day BOD (BOD_5), which is the most widely used parameter of organic pollution applied to both wastewater and ambient water quality. BOD_5 is a measure of the amount of dissolved oxygen consumed through biochemical oxidation during a 5-day incubation period at 20°C.[24]

General Trends. The generation of BOD is projected to increase substantially between 1975 and 2000. From estimated 1975 gross generation of almost 9 million tons, annual BOD generation is projected to increase to over 15 million tons by 2000 in the High Growth Scenario. In the Low Growth Scenario, gross generation is expected to increase more slowly, approaching 13 million tons annually by 2000. As seen in Table 6-7, which shows gross BOD generation by industry, municipal sewage was the greatest BOD source in 1975. Further, generation of BOD by municipal wastewater treatment facilities is expected to increase by 1.3 percent per year between 1975 and 2000 in the High Growth Scenario. This increase is attributable to population growth and greater centralization of sewage treatment.

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[22] U.S. Environmental Protection Agency, The Control of Pollution from Hydrographic Modifications, EPA 430/9-73-017, U.S. Government Printing Office, Washington, D.C., 1973.

[23] U.S. Environmental Protection Agency, Office of Water and Hazardous Materials, Quality Criteria for Water, Washington, D.C., July 1976.

[24] Metcalf and Eddy, Inc., Wastewater Engineering, McGraw-Hill, New York, New York, 1972, pp. 241-242.

TABLE 6-7
GROSS BOD GENERATION BY SELECTED INDUSTRY GROUPS
1975 AND 2000
(THOUSANDS OF TONS UNLESS NOTED)

	1975		2000						
			High Growth Scenario			Low Growth Scenario			
Industry	Generation	Percent of Total	Generation	Percent of Total	Percent of 1975	Generation	Percent of Total	Percent of 1975	Scenario Difference[a] (percent)
Municipal Wastewater Treatment Facilities	3,760	43	5,250	34	140	4,940	38	131	- 6
Pulp and Paper	1,740	20	3,540	23	203	2,760	21	158	-22
Meat Processing	820	9	1,210	8	147	1,070	9	129	-12
Sugar	530	6	590	4	113	510	4	96	-15
Fruit and Vegetable Processing	420	5	1,170	8	281	1,040	8	250	-11
Organic Chemicals	390	4	1,010	7	262	810	6	210	-20
Other	1,150	13	2,470	16	215	1,830	14	159	-26
Total[b]	8,840	100	15,420	100	174	13,070	100	148	-15

[a] Scenario difference is (Low Growth - High Growth) ÷ High Growth.

[b] Rounding may create inconsistencies in addition.

In contrast to the growth in BOD generation, net discharges of BOD are projected to decline between 1975 and 2000 in both scenarios. From a 1975 estimate of almost 3 million tons, annual net BOD discharges are projected to decline by an average of 0.6 percent per year in the High Growth Scenario (see Table 6-8). This decline is attributable solely to projected improvements in effluent quality achieved between 1975 and 1985. These improvements would be brought about by compliance with effluent limitations guidelines by industrial and municipal point sources. If such compliance is assumed, annual net BOD discharges under High Growth conditions would be halved by 1985. Between 1985 and 2000, however, annual net discharge levels are projected to resume increasing because of further population and economic growth, to about 1.8 million tons in the High Growth Scenario and slightly over 1.6 million tons in the Low Growth Scenario.

The divergence of trends in gross generation and net discharges is caused by BOD removal over and above the degree of treatment in 1975. If compliance with the FWPCA Amendments of 1972 and the Clean Water Act of 1977 lagged behind schedule, the trend toward reduced net discharges would be less equivalent. Net discharges could, in fact, show a steady increase. An upper bound on actual discharges has been estimated by applying the degree of abatement estimated for 1975 to projected gross BOD generation. As mentioned previously, the resulting upper bound estimate is termed "intermediate discharges." Figure 6-2 shows the estimated gross and net discharges in 1975 and projected gross, intermediate, and net discharges in 1985 and 2000 under the High Growth Scenario by region and for the nation. Noncompliance by industrial sources or municipal wastewater treatment facilities could greatly affect the amount of BOD discharged in each region.

Analysis of Trends in BOD. The national trends in BOD discharges reflect primarily developments in municipal wastewater treatment and several industrial sources. The main sources of gross generation and net discharges for the nation in 1975 and 2000 are shown in Figure 6-3. Regional trends in BOD reflect the regional distributions of these sources.

Full compliance with the FWPCA Amendments of 1972 and Clean Water Act of 1977 requires at least secondary treatment of all municipal treatment facilities by July 1 1983. The 1985 projections are predicated on full compliance and reflect at least 85 percent removal of BOD from the raw sewage entering municipal facilities. The treatment of municipal wastewater usually follows two steps: primary, which is physical in nature; and secondary, which is biological in nature. If further (tertiary) treatment is needed, a series of additional processes can be applied. Primary treatment begins with

TABLE 6-8
NET BOD DISCHARGES BY SELECTED INDUSTRY GROUPS 1975 AND 2000 (THOUSANDS OF TONS UNLESS NOTED)

	1975		2000						
			High Growth Scenario			Low Growth Scenario			
Industry	Discharges	Percent of Total	Discharges	Percent of Total	Percent of 1975	Discharges	Percent of Total	Percent of 1975	Scenario Difference[a] (percent)
Municipal Wastewater Treatment Facilities	1,510	53	1,290	73	85	1,210	77	80	- 6
Pulp and Paper	730	26	270	15	37	210	13	28	-22
Meat Processing	130	5	10	1	11	10	1	10	-13
Sugar	80	3	0	0	0	0	0	0	0
Fruit and Vegetable Processing	70	2	70	4	97	60	4	86	-11
Organic Chemicals	100	4	10	1	14	10	1	11	-21
Other	220	8	110	6	48	80	5	36	-26
Total[b]	2,840	100	1,760	100	62	1,580	100	56	-10

[a] Scenario difference is (Low Growth - High Growth) ÷ High Growth.

[b] Rounding may create inconsistencies in addition.

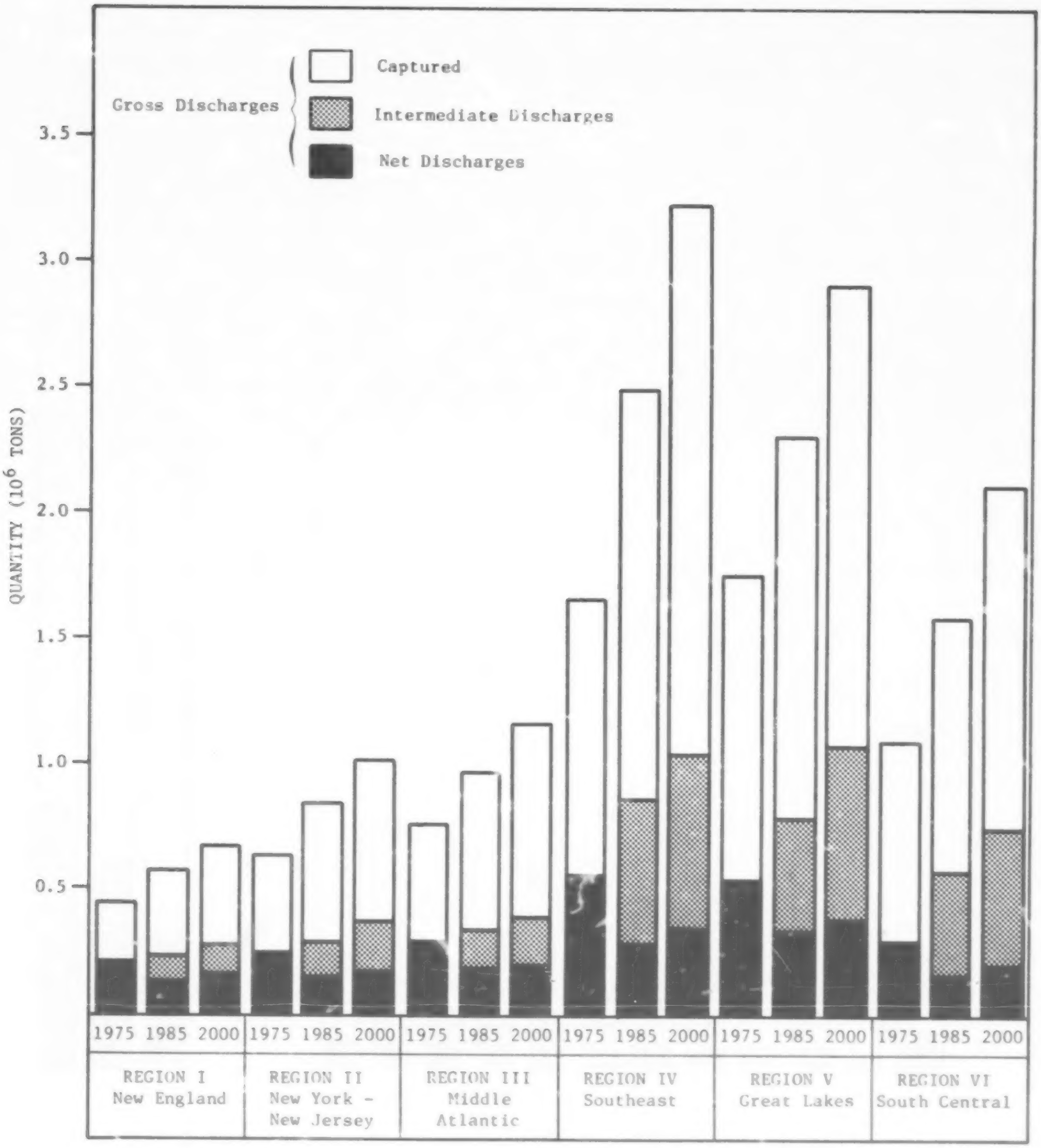


FIGURE 6-2
GROSS, INTERMEDIATE, AND NET BIOCHEMICAL OXYGEN DEMAND (BOD) DISCHARGES, BY REGION
HIGH GROWTH SCENARIO
1975, 1985, 2000

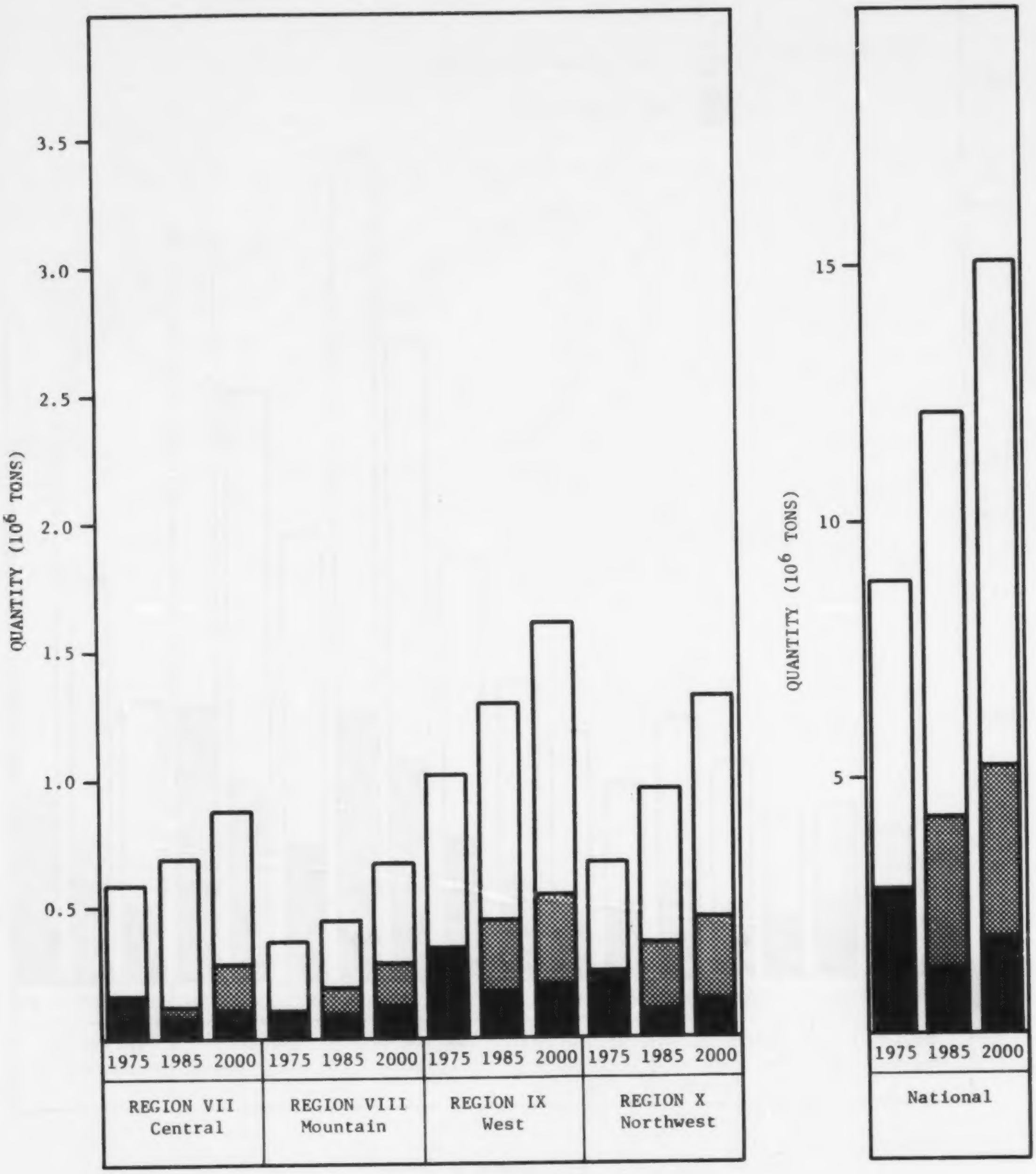
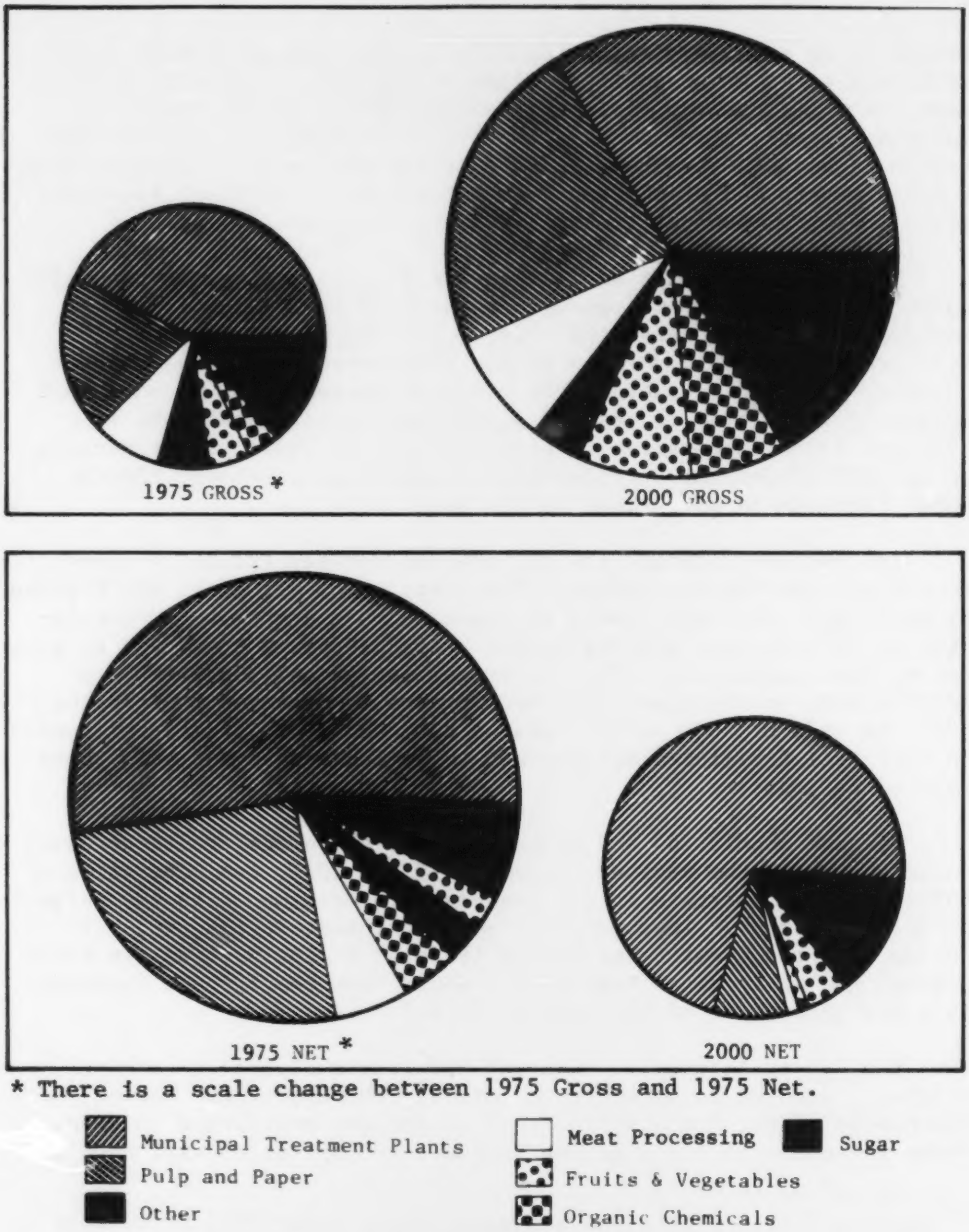


FIGURE 6-2
CONTINUED



* There is a scale change between 1975 Gross and 1975 Net.

FIGURE 6-3
GROSS AND NET DISCHARGES
OF BIOCHEMICAL OXYGEN DEMAND (BOD), BY INDUSTRY GROUP
HIGH GROWTH SCENARIO
1975 AND 2000

screening to remove grit; the wastewater then passes through sedimentation tanks where smaller solids settle out. Secondary treatment normally involves biological decomposition of the remaining suspended or dissolved organic matter; a settling tank removes the remaining solids from the wastestream; and the water is treated with a disinfectant and discharged to a watercourse. Tertiary treatment often involves chemical removal of plant nutrients.[25]

Municipal treatment facilities are forecast to remain the major point dischargers of BOD throughout the 1975 to 2000 period. Municipal treatment generated over 40 percent of all BOD in 1975; this proportion would decline in the High Growth Scenario to about one-third by 2000. However, the relative contribution by municipal treatment facilities to net BOD discharges would increase between 1975 and 2000. From slightly over one-half in 1975, the proportion of net BOD discharges attributable to municipal treatment plants would increase to 85 percent by the year 2000.

Two factors underlie the differences between trends in gross generation and net discharges. The fraction of all gross BOD treated by municipal treatment plants is expected to decrease by 2000 relative to 1975 because BOD discharges by industry are projected to grow faster than population. But the proportion of net BOD discharges attributable to municipal treatment plants is expected to increase over the 1975 to 2000 period because BOD removal requirements imposed on municipal facilities are assumed to be less stringent than those imposed on industry.[26]

Because population and centralization of sewage treatment would increase in all the regions between 1975 and 2000, the generation of BOD also would increase in all regions. The regions with the largest projected increases in population--the Southeast Region (Federal Region IV), the Great Lakes Region (Federal Region V), and the South Central Region (Federal Region VI)--would have the largest increases in gross generation of BOD (see Table 6-9).

Because efficiency in removing BOD from municipal treatment plants is assumed to increase uniformally throughout the nation, net discharges of BOD are also expected to reflect population changes. Those regions with the greatest increase in population will have the

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[25] Steffan, A.S., Effects and Removability of Industrial Pollutants in a Municipal System, Joint Municipal/Industrial Seminar on Pretreatment of Industrial Wastes, U.S. Environmental Protection Agency, 1978, p. 225.

[26] This is a result of institutional rather than technological factors.

TABLE 6-9
POPULATION GROWTH AND TRENDS IN GROSS GENERATION OF BOD, BY REGION
HIGH GROWTH SCENARIO
1975 and 2000

	1975		2000			
			Population		Gross BOD	
Federal Region	Population (Millions)	Gross BOD (Thousands of Tons)	Number (Millions)	Percent of 1975	Quantity (Thousands of Tons)	Percent of 1975
I. New England	12	450	14	117	690	154
II. New York/New Jersey	25	600	27	108	1,030	170
III. Middle Atlantic	24	740	28	116	1,130	152
IV. Southeast	35	1,630	48	137	3,030	186
V. Great Lakes	45	1,720	50	112	2,880	167
VI. South Central	22	1,070	30	136	2,100	196
VII. Central	11	590	12	109	830	141
VIII. Mountain	6	360	8	133	670	186
IX. West	25	1,000	32	131	1,590	159
X. Northwest	7	670	9	134	1,310	195
Total	213	8,840	262	122	15,420	175

smallest decline in net discharges. As a result, Federal Regions IV, V, and VI would not only have the largest increase in BOD generation but would also have the lowest decline in BOD discharges.

The pulp and paper industry is expected to be the major industrial source of BOD between 1975 and 2000. From an estimated 1.7 million tons of BOD generated in 1975, gross generation is expected to double by 2000 in the High Growth Scenario. This would occur in association with an almost 4 percent per year increase in constant dollar output over this time period. In the Low Growth Scenario, dollar output in the pulp and paper industry would increase by slightly less than 3 percent per year, resulting in an increase in gross BOD generation of approximately 1 million tons. Improvements in the efficiency of the pulp and paper industry in removing BOD from entering wastestreams would decrease net discharges of BOD from 730 thousand tons in 1975 to 260 thousand tons in the High Growth Scenario.

Within this industrial category, the major generators of BOD are associated with bleached kraft and sulfite pulp production. Production of kraft pulp, for corrugated boxes and other products, was estimated to generate about half of all BOD in the pulp and paper industry in 1975. However, a shift away from the production of bleached kraft pulp to unbleached kraft (a less significant generator of BOD) is anticipated during the 1975 to 2000 period. About half of all kraft pulp was bleached in 1975, but this proportion is expected to decline to less than 15 percent in 2000. This is expected to result in lower BOD loadings in the raw wastestreams of kraft pulp mills by 2000. The relative contribution of BOD from kraft pulp mills is thus reduced from half to only one-fourth of all BOD generated by the pulp and paper industry. As a result, generation of BOD by the industry as a whole would grow much more slowly than the industry's dollar output over the same period.

Although the quantity of BOD in the raw wastestreams of pulp and paper industries is expected to increase between 1975 and 2000, net discharges of BOD from these sources are projected to decline substantially. In 1975, it was estimated that more than half of the BOD in pulp and paper wastestreams was removed through treatment. However, almost three-quarters of a million tons were still released to the environment that year. If full compliance with effluent limitations guidelines were achieved by the industry, net BOD discharges would decline to a quarter million tons annually by 2000 in the High Growth Scenario.

The impacts of compliance with BAT standards in the pulp and paper industry are highly evident in the production of sulfite pulp. The portion of BOD removed from the wastestreams of sulfite mills would increase from about 50 percent in 1975 to over 90 percent by 1985 if full compliance with Federal regulations was achieved. However, it should be noted that the treatment of wastewater from sulfite pulp production is complex and costly,[27] and full compliance may not be achieved. In such case, the projected substantial reduction in net BOD discharges by the industry would be too optimistic.

The geographic distribution of the pulp and paper industry is indicated in Table 6-10. There is substantial activity in all 10 regions. However, Federal Regions IV and V are expected in the year 2000 to account for almost half of the constant dollar output of the industry in the High Growth Scenario. This would add to the regional disparity in gross generation of BOD. However, mitigating this fact are the improvements in removal rates which would be attained with full compliance. Thus, Federal Regions IV and V, which were identified as facing potential BOD problems because of population growth, would benefit more than other regions from the increased abatement efficiency anticipated in the pulp and paper industry. In particular, full compliance with effluent limitations guidelines by the pulp and paper industry in the Great Lakes Region (Federal Region V) would reduce net discharges from over 100 thousand tons in 1975 to under 50 thousand tons in 2000 in the High Growth Scenario. This would greatly reduce the relative importance of the pulp and paper industry as a source of BOD in that region.

The second largest industrial generator of BOD is the meat products processing industry. It was estimated that 820 thousand tons of BOD were generated in 1975 by this industrial category. During the 1975 to 2000 period, gross generation is expected to increase at an annual rate of over 1.5 percent in the High Growth Scenario. Packinghouse operations are expected to be the major BOD sources within the meat products processing industry, accounting for approximately 60 percent of total gross BOD generation. Slaughterhouses and poultry processing are also expected to be major generators of BOD within the industry.

Water pollution control devices used by the meat products processing industry include flow equalization tanks, screens, catch basins, and dissolved air flotation equipment during in-plant pretreatment and either anaerobic processes, aerobic lagoons, activated sludge, or high-rate trickling filters during secondary treatment of wastes.

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[27] U.S. Environmental Protection Agency, Economic Analysis of Proposed Effluent Guidelines: Pulp, Paper and Paperboard Industry, EPA 230/1-73-023, Washington, D.C., September 1973.

TABLE 6-10
OUTPUT OF THE PULP AND PAPER INDUSTRY, BY REGION: HIGH GROWTH SCENARIO
1975 and 2000

Region	1975		2000	
	Output ($Millions)[a]	Percent of Total	Output ($Millions)[a]	Percent of Total
I. New England	$ 2,510	14	$ 4,960	11
II. New York/New Jersey	1,660	9	2,800	6
III. Middle Atlantic	1,577	9	3,475	7
IV. Southeast	3,758	20	11,915	25
V. Great Lakes	5,247	28	12,396	26
VI. South Central	1,337	7	4,656	10
VII. Central	363	2	1,009	2
VIII. Mountain	53	-	249	1
IX. West	662	4	1,976	4
X. Northwest	1,379	7	3,579	8
Total	18,530	100	47,015	100

[a] Constant 1971 dollars.

It is estimated that, in 1975, such treatment removed over 80 percent of BOD from meat products processing industry wastestreams, resulting in net discharges of 130 thousand tons in that year. Compliance with effluent limitations guidelines over the 1975 to 1985 period is expected to reduce discharges further, to about 10 thousand tons annually by 2000 in the High Growth Scenario.

The regions which benefit from this major decrease in net meat products processing discharges are the Middle Atlantic, Southeast, Great Lakes, South Central, and Central Regions (Federal Regions III, IV, V, VI, and VII). In the Central Region, net discharges of BOD from meat processors would be reduced from approximately 25 thousand tons in 1975 to 15 thousand tons in 2000 if full compliance were achieved by the industry (High Growth Scenario). Since the meat products processing industry is the only major industrial source of BOD in that region, the virtual elimination of net discharges of BOD by that industry coupled with low projected regional population growth (9 percent over the period) results in a sharp percentage decline in net discharges between 1975 and 2000, the greatest decline among the regions.

As mentioned earlier, other major sources of BOD in 1975 were sugar processing, organic chemicals, and fruit and vegetable processing. Full compliance with effluent guidelines would result in almost total elimination of wastewater discharges of BOD by these industries.

In summarizing the analysis of trends in BOD, it should be noted that the severity of BOD problems within any particular region or industry will depend on the degree of compliance with effluent limitations guidelines. The Southeast Region (Federal Region IV) best exemplifies this. Because of population growth and increased output in the pulp and paper, meat processing, fruit and vegetable processing, and organic chemicals industries, this region is expected to have the greatest absolute increases in generation of BOD. As a result, if the assumption is made that very few treatment plants and industries would meet pollution control mandates, Federal Region IV must expect increasing BOD problems. In the event of full compliance, Federal Region IV, with the greatest decline in net discharges, would not face major problems through 2000.

6.2.3 Suspended Solids

HIGHLIGHTS OF SECTION 6.2.3

- The generation of suspended solids residuals is projected to almost triple under high economic growth conditions, but net discharges are expected to decrease sharply because of treatment.

- The aluminum industry, particularly the bauxite refining process, and the coal preparation industry account for most generation of suspended solids.

- However, currently the coal preparation industry has virtually no net discharges of suspended solids, and the aluminum industry is projected to reach a similar level of control by 1985, assuming full compliance with effluent guidelines. Municipal wastewater treatment facilities then would account for over 75 percent of net discharges of suspended solids under high economic growth conditions.

- The South Central Region (Federal Region VI) is projected to experience the largest relative decline in suspended solids discharges because it is the site of most U.S. bauxite refining.

Introduction

"Suspended solids" is a general term for undissolved organic and inorganic particulate matter in water. High concentrations of these suspended solids increase water turbidity and may result in silt deposition in lakes and streams. These problems can affect fish and aquatic plant life, alter streams, and reduce the storage capabilities of reservoirs.[28] A high level of water turbidity also interferes with recreational use and aesthetic enjoyment.[29] High turbidity in drinking water supplies can have an adverse affect on chlorine disinfection as suspended matter provides areas where microorganisms do not come into contact with the chlorine disinfectant.

Suspended solids can harm fish and fish food populations in four ways, by (a) killing them or reducing their growth and resistance to disease, (b) killing their larvae and eggs, (c) modifying natural movements and migrations, and (d) reducing the abundance of food organisms.[30] Siltation places a stress on stream and lake ecosystems, with the result that the diversity of species present may fall sharply.

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[28] The MITRE Corporation, Metrek Division, National Environmental Impact Projection No. 1, MTR-7905, McLean, Virginia, December 1978.

[29] U.S. Environmental Protection Agency, Office of Water and Hazardous Materials, Quality Criteria for Water, Washington, D.C., July 1976.

[30] European Inland Fisheries Advisory Commission, "Water Quality Criteria for European Freshwater Fish," International Journal Air-Water Pollution, Vol. 9, 1965, p. 151.

Although discharges of suspended solids from point sources are considered a problem, by far the greatest source of this pollutant is erosion which threatens water quality and soil productivity in many parts of the United States.[31] Suspended solids discharges from erosion are discussed in Section 6.3. This section is limited to point source discharges.

Discharge Trends for Suspended Solids

General Trends. The amount of suspended solids in untreated municipal and industrial wastewaters is expected to increase sharply as population and economic activity grow. Forecasts of gross generation show substantially higher levels of suspended solids in wastewaters by 2000 in both the High and Low Growth Scenarios. Total gross generation of suspended solids is expected to increase from over 60 million tons in 1975 to almost 175 million tons in 2000 in the High Growth Scenario and to almost 140 million tons in the Low Growth Scenario. However, full compliance with BAT standards by 1985 would cause a downward trend in net suspended solids discharges. Our forecasts show a decline in net discharges of suspended solids in both scenarios with full compliance from almost 6 million tons in 1975 to less than 2 million tons in 2000 in the High Growth Scenario and approximately 1.5 million tons in the Low Growth Scenario.

Figure 6-4 depicts gross generation of suspended solids, net discharges, and intermediate discharges under the High Growth Scenario. Intermediate discharges are calculated under the assumption that pollution control in each industry does not improve over the 1975 level. The figure demonstrates the dominance of Federal Regions III, IV, and V in the generation of suspended solids and illustrates the radical drop in net discharges--sixfold by 2000--that would occur in Federal Region VI under the assumption of full compliance.

Analysis of Trends. Effluents from municipal wastewater treatment and four industries account for virtually all gross generation of suspended solids by point sources. The four industries are pulp and paper, aluminum, steel, and coal preparation. As shown in Table 6-11, the coal preparation and aluminum industries together account for almost three-fourths of total gross generation.

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[31] U.S. General Accounting Office, Report to Congress: To Protect Tomorrows Food Supply, Soil Conservation Needs Priority Attention, CED-77-30, U.S. Government Printing Office, Washington, D.C., 1977.

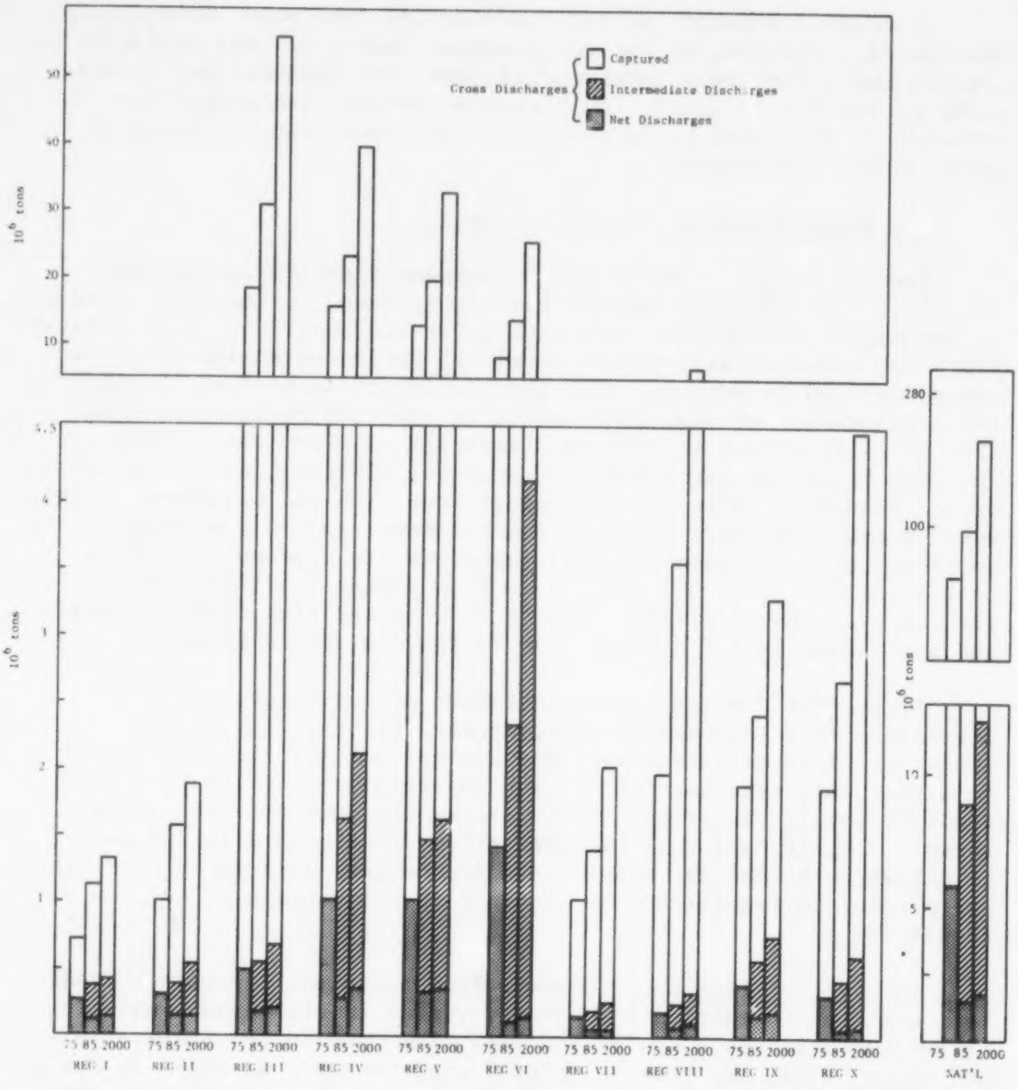

FIGURE 6-4
GROSS INTERMEDIATE AND NET DISCHARGES OF SUSPENDED SOLIDS, BY REGION
1975, 1985, 2000

TABLE 6-11

DISCHARGES AND ABATEMENT PERCENTAGES OF SUSPENDED SOLIDS BY INDUSTRIAL GROUP

1975, 1985, 2000

(THOUSANDS OF TONS UNLESS NOTED)

	1975			1985				2000				Percent Abated (In 1985 & 2000, Both Scenarios)
				High Growth Scenario		Low Growth Scenario		High Growth Scenario		Low Growth Scenario		
Industry	Gross	Net	Percent Abated	Gross	Net	Gross	Net	Gross	Net	Gross	Net	
Coal Preparation	36,800	8	99.8%	61,650	1	50,250	1	119,150	12	88,700	9	99.9%
Aluminum	6,750	1,100	84	12,300	1	11,300	1	23,700	1	20,950	1	99.9
Municipal Wastewater Treatment Facilities	3,900	1,500	62	4,900	1,200	4,750	1,175	5,400	1,300	5,100	1,260	75
Steel	3,300	670	80	4,700	5	4,500	4	5,700	6	5,300	5	99.9
Pulp and Paper	2,700	1,100	60	4,800	180	4,200	160	5,000	200	4,000	170	96
Total[a]	61,400	5,700	91	99,400	1,500	85,100	1,500	173,700	1,800	136,500	1,600	98

[a] Rounding may create inconsistencies in addition.

Gross generation of suspended solids by the coal preparation industry is projected to rise from about 40 million tons annually in 1975 to 120 million tons by 2000 in the High Growth Scenario and to 90 million tons in the Low Growth Scenario--annual growth rates of 4.5 percent and 3.3 percent. The estimated 1975 rate of control of suspended solids in coal preparation was very high, and will remain high. Thus, net discharges after treatment are expected to grow only at the rate industry output grows, increasing slowly from an insignificant base amount.

Coal preparation activities occur almost exclusively in four regions--Middle Atlantic (Federal Region III), Southeast (Federal Region IV), Great Lakes (Federal Region V), and Mountain (Federal Region VIII). For this reason, these regions account for almost 90 percent of gross suspended solids generation by point sources in 2000. However, the extremely high removal rates achieved by the coal preparation industry mean that it does not determine the distribution among regions of net suspended solids discharges.

The aluminum industry, particularly bauxite refining, also accounts for significant gross generation of suspended solids. Gross generation of suspended solids in bauxite refining is estimated at almost 7 million tons for 1975 and would rise to 24 million tons by 2000 in the High Growth Scenario. At the same time, compliance with effluent limitations guidelines would reduce the net discharge levels substantially, from over 1 million tons in 1975 to only 1 thousand tons by 2000.

Bauxite refining is located mainly in the South Central Region (Federal Region VI). In 1975, 17 of the 19 million tons of bauxite refined in the United States were refined in Federal Region VI. This production generated almost 1 million tons of suspended solids in that year, and the industry is projected to increase annual output in Federal Region VI by almost 4 percent annually. However, compliance with effluent guidelines would reduce net discharges by this industry by a factor of almost a thousand by 2000.

Municipal sewage treatment is also an important source of suspended solids discharges. Projected gross generation would increase from about 4 million tons in 1975 to 5.5 million tons in 2000 in the High Growth Scenario and 5 million tons in the Low Growth Scenario. Even under an assumption of complete compliance with effluent discharge controls, net discharges are projected to decline very little over the 1975 to 2000 period. The projections show a decrease in annual discharge from 1.5 million tons in 1975 to 1.3 million tons in 2000 in the High Growth Scenario. High net discharges of suspended solids from municipal facilities are expected to persist because of continued population growth and because the required secondary treatment does not remove more than about three-fourths of the suspended solids from raw municipal wastewaters. Addition of tertiary treatment would not affect suspended solids discharges greatly.

Population growth and increasing centralization of sewage treatment would result in significant net discharges of suspended solids from municipal facilities throughout the country in the coming years. Because sewage treatment facilities would be the main point source of suspended solids if industry complies with effluent guidelines, the regional distribution of suspended solids discharges is projected to become much more widely dispersed in 2000. Federal Regions III, IV, V, and VI would no longer have disproportionate shares of net discharges (Figure 6-4).

6.2.4 Dissolved Solids

HIGHLIGHTS OF SECTION 6.2.4

- Although water quality criteria for dissolved solids exist, there are no national effluent guidelines. Control of dissolved solids typically occurs only coincidentally in the control of other pollutants.

- Gross generation of dissolved solids by point sources is expected to increase from 13 million tons in 1975 to 32 million tons in 2000 under High Growth conditions while net discharges would double to 17 million tons in 2000. The increase in net discharges would follow growth in gross generation because treatment improvements are not expected during that period.

- Important industrial sources of dissolved solids discharges include the inorganic and organic chemicals, coal preparation, electric utilities, and coal mining industries.

- The Northwest Region (Federal Region X) is projected to experience the largest percentage increases in generation and net discharges of dissolved solids because of sizable increases in coal-fired and nuclear electric generation in that region.

Introduction

Dissolved solids generally consist of inorganic salts and small amounts of organic matter. The principal dissolved substances are dissociated ions from sodium chloride, calcium chloride, sodium carbonate, and other inorganic salts.

High concentrations of dissolved solids in drinking water can cause adverse health effects[32] and bad taste. Treatment of water with higher concentrations of dissolved solids costs more, and water pipes may corrode faster. Excessive dissolved solids concentrations can preclude use of water supplies for irrigation as well.

Discharge Trends for Dissolved Solids

General Trends. Gross generation of dissolved solids by point sources is expected to double, from about 15 million tons in 1975 to over 30 million tons in 2000 in the High Growth Scenario and to around 25 million tons in the Low Growth Scenario. Compliance with BAT standards for other pollutants would remove some of the dissolved matter from wastewaters coincidentally. Nonetheless, net discharges of dissolved solids also are projected to double between 1975 and 2000, from 8 million tons in 1975 to 17 million tons in 2000 in the High Growth Scenario and to 14 million tons in the Low Growth Scenario.

All Federal Regions are projected to experience a great increase in gross generation of dissolved solids and, because only coincidental abatement would occur, as much increase in net discharges (Figure 6-5).

No dissolved solids estimates are available for municipal sewage treatment facilities. Thus, dissolved solids levels, particularly from gross or raw wastestream values, are probably understated in this analysis.

Analysis of Trends. Five industrial groups are expected to remain important sources of dissolved solids: electric utilities, inorganic chemicals, organic chemicals, coal preparation, and coal mining (Figure 6-6). Electric utilities were the largest source in 1975, and our projections indicate they will remain the largest source throughout the 1975 to 2000 period. They generated 4 million tons of dissolved solids in 1975. By 2000, this is expected to rise to over 10 million tons in the High Growth Scenario and to 9 million tons in the Low Growth Scenario, representing annual growth rates of over 4 percent and 3.5 percent. Net discharges of dissolved solids by coal-fired utilities would increase from 2.7 million tons in 1975 to just about 7 million tons in 2000 in both scenarios. Because nuclear generated electricity is expected to be the fastest growing

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[32] U.S. Environmental Protection Agency, Office of Water & Hazardous Materials, Quality Criteria for Water, Washington, D.C., July 1976, p. 205.

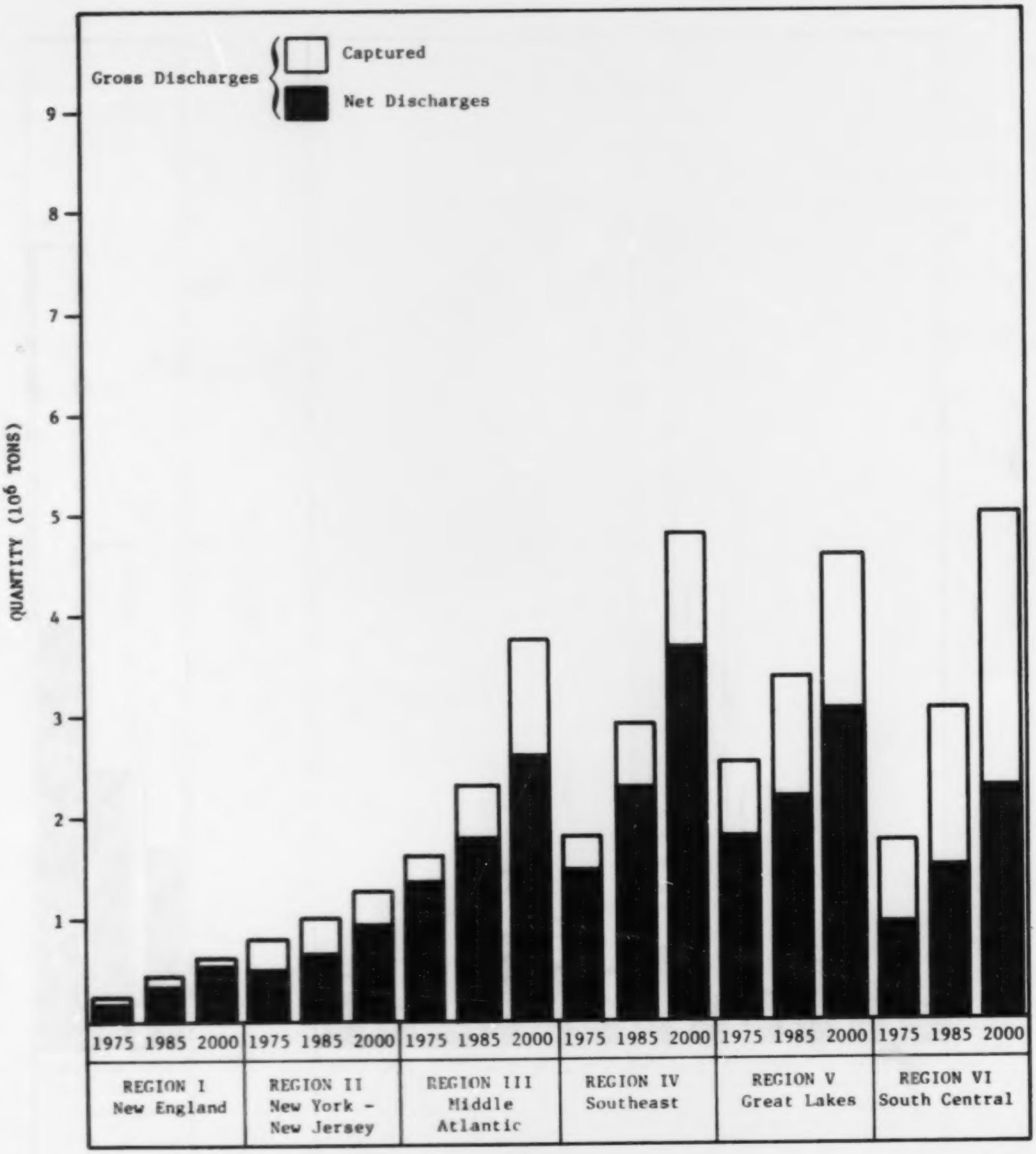

FIGURE 6-5
GROSS AND NET DISSOLVED SOLIDS DISCHARGES, BY REGION
HIGH GROWTH SCENARIO
1975, 1985, 2000

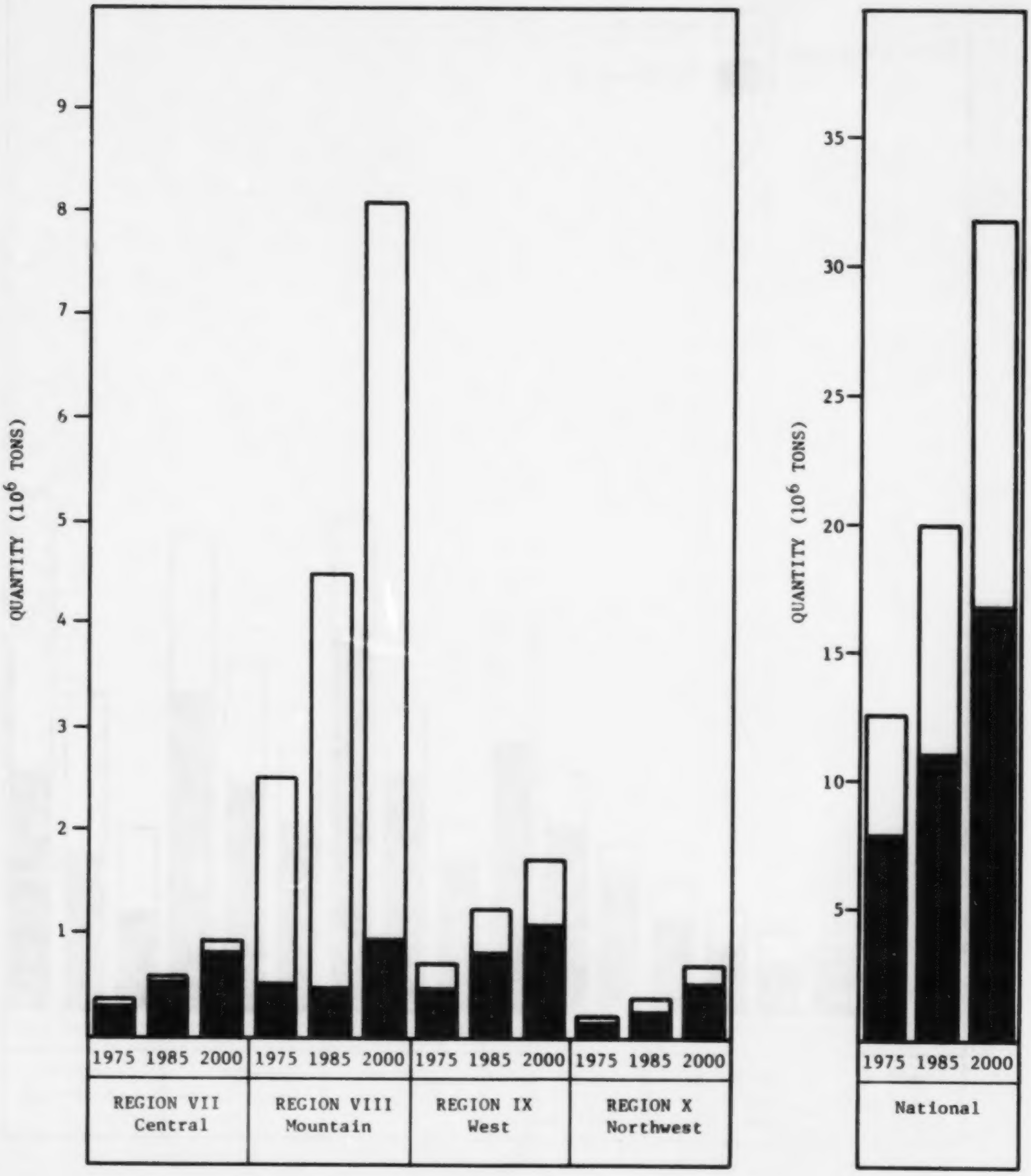

FIGURE 6-5
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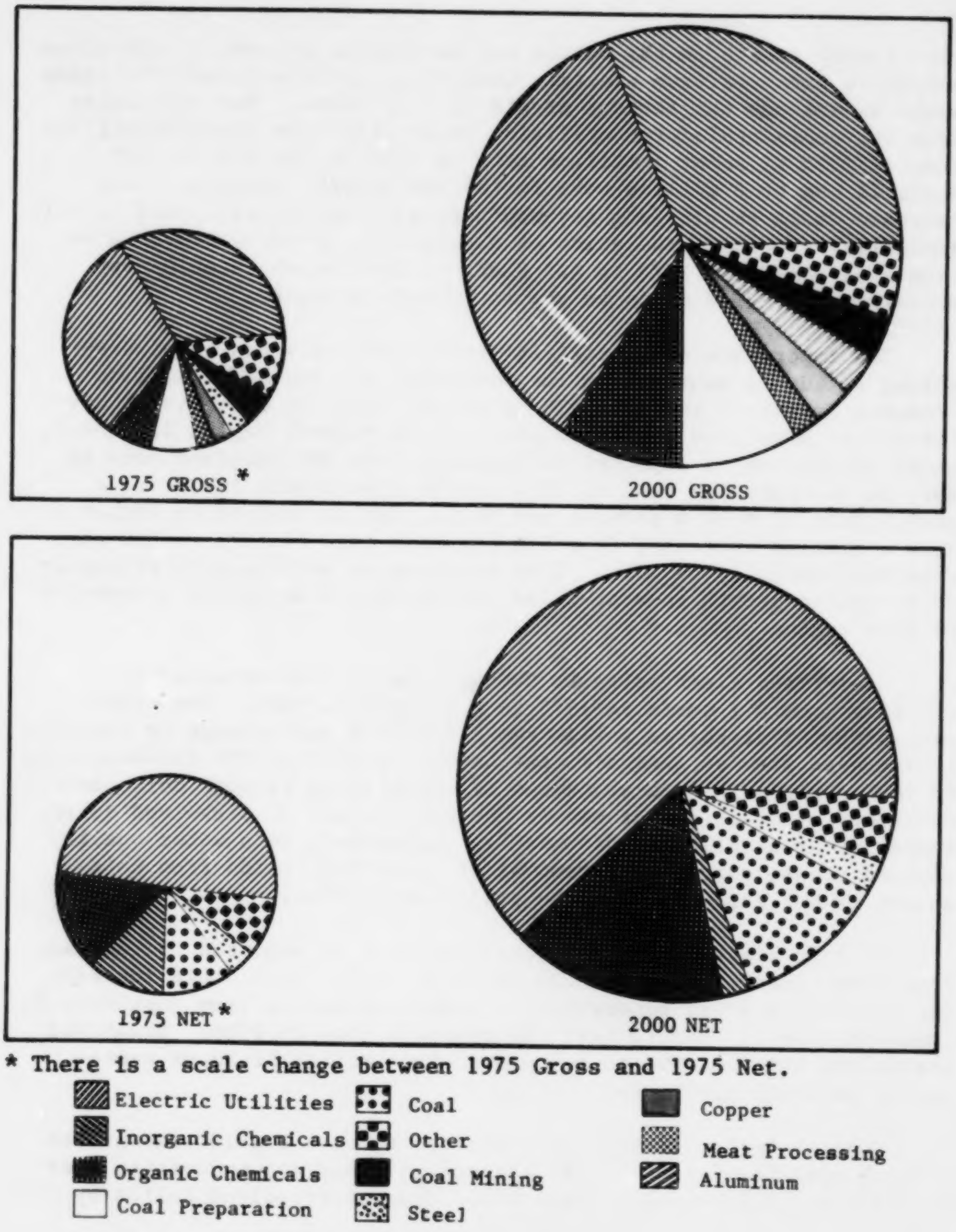

* There is a scale change between 1975 Gross and 1975 Net.

FIGURE 6-6
GROSS AND NET DISCHARGES
OF DISSOLVED SOLIDS, BY INDUSTRY GROUP
HIGH GROWTH SCENARIO
1975 AND 2000

electricity source in the nation and because no control of dissolved solids is expected from electric utilities, nuclear-fueled utilities would experience the fastest growth in discharges. The discharges from the nuclear electric utilities would rise from one-half million tons in 1975 to about 4 million tons in 2000 in the High Growth Scenario and to 3 million tons in the Low Growth Scenario. This increase would result from assumed expansion of nuclear power in both scenarios. Nuclear generation of electricity is estimated to grow from 0.6 quads[33] in 1975 to 4.5 quads in 2000 in the High Growth Scenario and to 3.6 quads in the Low Growth Scenario.

The importance of electricity generation as a source of dissolved solids is manifest in the Northwest and Southeast Regions (Federal Regions X and IV). The greatest relative increase in discharges of dissolved solids would occur in Federal Region X. There, gross generation is expected to increase from 160 thousand tons in 1975 to 720 thousand tons in 2000 in the High Growth Scenario, a growth rate of over 6 percent per year. Net discharges in Region X show a similar increase, from 130 thousand tons in 1975 to 560 thousand tons annually by 2000. This increase is attributable primarily to projected growth in coal-fired and nuclear electricity generation in this region.

Coal-fired electricity in Federal Region X is expected to increase from 0.1 quads in 1975 to 1.5 quads in 2000. The gross generation of dissolved solids resulting from this change is expected to increase from an insignificant amount in 1975 to 290 thousand tons in 2000. Although some abatement is anticipated through coincidental treatment of other pollutants or the enforcement of dissolved solids standards upon utilities discharging wastewaters into water quality limited areas, significant removal of dissolved solids from this source is not expected over the projection period.

Nuclear electricity in Federal Region X is expected to increase from 0.04 quads in 1975 to 0.25 quads by 2000. This would increase the industry's gross generation of dissolved solids from just over 30 thousand tons in 1975 to over 180 thousand tons in 2000. Dissolved solids are not expected to be removed from boiler blowdown wastewaters prior to discharge.

Federal Region IV is also projected to have significant growth in both coal-fired and nuclear electricity generation capacity over the 1975 to 2000 period. Gross generation of dissolved solids by coal-fired plants is expected to increase to 1 million tons by 2000, while dissolved solids from nuclear plants are projected to increase to 670 thousand tons. None of this is expected to be captured by pollution control treatment over the period. Coal preparation also accounts for a significant amount of gross generation of dissolved solids in Federal Region IV, but strict control in accordance with effluent limitations guidelines would limit net discharges somewhat; they would increase only from 80 thousand tons in 1975 to 130 thousand tons by 2000 in the High Growth Scenario.

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[33] One quad = 1 quadrillion Btu; 1 quad is the energy equivalent of more than 170 million barrels of crude oil.

The next largest point source of dissolved solids in the nation is the inorganic chemicals industry. Gross generation of dissolved solids is expected to increase as the industry grows, rising from 4 million tons in 1975 to 10 million tons by 2000 in the High Growth Scenario and to 8 million tons in the Low Growth Scenario. However, net discharges from inorganic chemicals production are expected to decline from 1975 levels. In the High Growth Scenario, net dissolved solids discharges, which were estimated to approach 950 thousand tons in 1975, are projected to total only 390 thousand tons annually by 2000.

The inorganic chemicals industry is by far the major source of dissolved solids in the Mountain Region (Federal Region VIII). There, the inorganic chemicals industry is expected to generate about 2 million tons in 1975 and 7 million tons by 2000. A high proportion is expected to be controlled over the period, so that projected net discharges would actually decline from 340 thousand tons in 1975 to 200 thousand tons by 2000 in the High Growth Scenario.

The coal preparation industry is also projected to be a major generator of dissolved solids over the 1975 to 2000 period. In the High Growth Scenario, gross generation is expected to rise from 900 thousand tons in 1975 to almost 3 million tons in 2000. The projection for the Low Growth Scenario in 2000 is 2.25 million tons. Net discharges over this period are expected to double, rising from 450 thousand tons in 1975 to 1 million tons in 2000.

The organic chemicals industry is also projected to be an important source of dissolved solids discharges. Discharges would show an annual growth rate of 3.3 percent over the 1975 to 2000 period in the High Growth Scenario. The expected increase is from 1.2 million tons in 1975 to 2.7 million tons in 2000. This doubling of discharges would be attributable to the rapid economic expansion projected for the industry.

Within the organic chemicals industry, the pesticides and agricultural chemicals industry is expected to be the largest generator of dissolved solids over the 1975 to 2000 period. Discharges are estimated to rise from 930 thousand tons in 1975 to 1.5 million tons by 2000 in the High Growth Scenario. The dyes and dye intermediates industry is expected to rise from just over 200 thousand tons in 1975 to about 500 thousand tons in 2000 in the High Growth Scenario.

The two major forms of dissolved solids discharged by the organic chemicals industry are chloride and sulfate ions. These are not abated under existing regulations. Chloride discharges are expected to increase from 370 thousand tons in 1975 to 650 thousand tons in 2000 in the High Growth Scenario. The pesticides and agricultural chemicals industry is expected to produce the most chloride pollution, with chloride discharges expected to rise from 250 thousand tons in 1975 to 400 thousand tons in 2000.

Discharges of sulfate ions are expected to rise from 80 thousand tons in 1975 to 220 thousand tons in 2000. The greatest part of sulfate discharges is attributable to manufacturing dyes and dye intermediates. Sulfates, like chloride, will not be abated even if full compliance with BAT standards is achieved.

The organic chemicals industry is a major point source of dissolved solids in the Southeast and South Central Regions (Federal Regions IV and VI). Dissolved solids discharges by this industry are projected to increase at 4.5 percent per year until 2000.

In summary, dissolved solids could become a more significant water quality problem in many areas of the country between now and 2000. Particular sources of the problem are likely to be discharges from electric utilities (boiler blowdown) and the organic chemicals industry.

6.2.5 Nitrogen

HIGHLIGHTS OF SECTION 6.2.5

- The generation of nitrogen compounds is expected to increase by about one-third to 1.3 million tons in 2000 under high economic growth conditions.
- Net discharges of nitrogen compounds are also expected to increase, but because there is some coincidental control of these discharges, the rate of increase is not rapid.
- Municipal sewage treatment plants are expected to be the major point dischargers of nitrogen compounds. Major industrial dischargers will be the meat products processing, organic chemicals, fats and oils, and steel industries.

- The Southeast Region (Federal Region IV) is expected to be the greatest generator of nitrogen compounds and is expected to be the major regional source of net discharges by 2000.

Introduction

Nitrogen in its many forms plays a fundamental role in the aquatic environment. It is apparent that ecological imbalances in the natural environment such as algal blooms have been caused, in part, by the excessive discharges of nitrogenous materials to natural water-ways.[34] Nitrates and ammonia are the main compounds of nitrogen implicated in water quality problems.

High intake of nitrates can be hazardous to warm-blooded animals (particularly the very young) under some circumstances. Nitrite ion is formed from nitrate or ammonium ions by certain microorganisms found in water, soil, and sewage. In oxygenated natural water systems nitrite is rapidly oxidized, thus depleting free oxygen.

Treated wastewater effluent containing ammonia has several undesirable characteristics. Oxidation of the ammonia consumes dissolved oxygen in receiving waters. Ammonia also can be toxic to fish life, corrode copper fittings in pipes, and increase the amount of chlorine required for disinfection.

Among the major point sources of nitrogen are municipal and industrial wastewaters, septic tanks, and feedlot discharges.

Discharge Trends for Nitrogen

General Trends. Generation of nitrogen compounds is expected to increase between 1975 and 2000. Annual generation is projected to increase from 915 thousand tons in 1975, by approximately 1.4 percent per year in the High Growth Scenario to a level of 1.3 million tons in 2000. In the Low Growth Scenario, generation is expected to increase by about 1 percent per year to a level of 1.1 million tons annually by 2000.

Net discharges of nitrogen are also expected to increase over the period from 1975 to 2000, although at a slower rate than gross generation. Annual net discharges of nitrogen are expected to increase from a 1975 estimate of approximately 800 thousand tons, by about 10 percent over the entire period in the High Growth Scenario and 3 percent in the Low Growth Scenario. These trends are shown in Figure 6-7. Removal of other pollutants by industrial and municipal sources is expected to remove some nitrogen from wastewaters coincidentally. In addition to this coincidental removal, some facilities which discharge into water quality-limited receiving waters have nitrogen effluent limitations imposed. These limitations serve to achieve even greater removal efficiency than the coincidental removal. These two factors, coincidental removal and nitrogen effluent limitations, combine to offset the effect of economic growth. This can be seen by comparing 1975 and 1985 estimates. From 790 thousand tons in 1975, net discharges of nitrogen are projected in the High Growth Scenario to decline to 735 thousand tons annually by 1985. Between 1985 and 2000, however, in a period when no additional controls on discharges are anticipated, net discharges would increase at an annual rate of 1.2 percent as the economy continues to expand.

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[34] U.S. Environmental Protection Agency, Environmental Pollution Control Alternatives: Municipal Wastewater, Washington, D.C., 1976.

Analysis of Trends. Municipal sewage treatment facilities are expected to be the predominant point sources of nitrogen throughout the period to 2000. Generation of nitrogen by these facilities would increase from an estimated 600 thousand tons in 1975 to about 800 thousand tons by 2000 in the High Growth Scenario. Net discharges of nitrogen from municipal sewage treatment facilities increase similarly. From 600 thousand tons in 1975, net discharges of nitrogen are projected to increase to just over 750 thousand tons annually by 2000. The trend in discharges follows the trend in gross generation because improved treatment to remove nitrogen is not assumed to be adopted on a widespread basis. More sophisticated treatment requiring chemical or additional biological processes is needed to remove significant quantities of nitrogen from muncipal sewage wastewaters.

Continued growth in population and increasing urbanization are major factors behind the projected increase of nitrogen discharges by municipal treatment facilities. Compliance with the Clean Water Act is assumed to mitigate the impacts of higher waste loads slightly; net discharges of nitrogen would increase by 26 percent by 2000 in the High Growth Scenario, while nitrogen in raw sewage would increase by 29 percent.

As mentioned in earlier sections, inflows of raw sewage are expected to increase in all regions because population is growing in all regions. The extent of the problem in each region relates to the regional rate of population growth and the rate at which treatment is centralized. The fastest growing regions are thus the regions that are projected to face a relatively larger nitrogen problem from municipal sewage treatment facilities--the Southeast (Federal Region IV), South Central (Federal Region VI), Northwest (Federal Region X), and Mountain (Federal Region VIII).

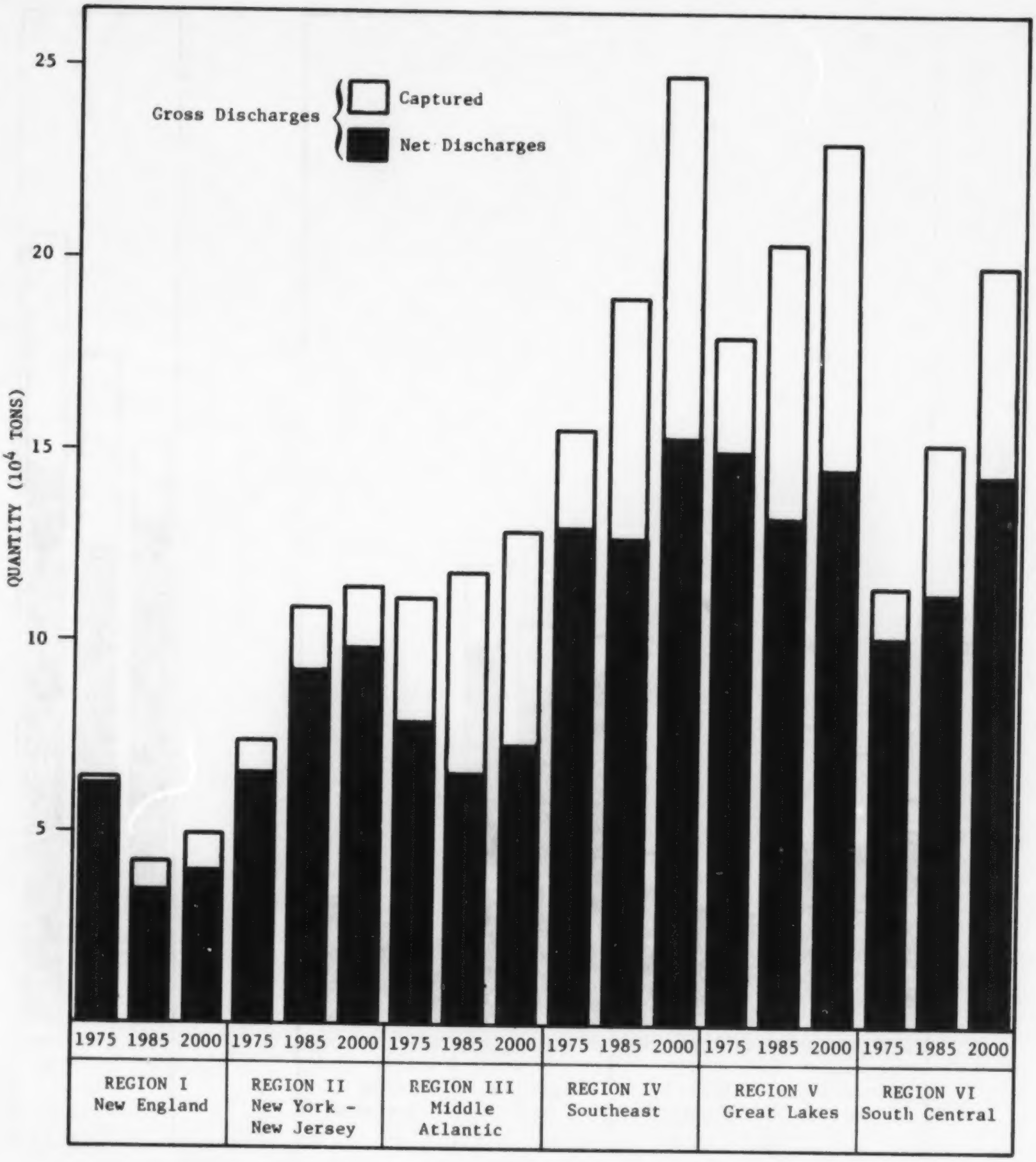

FIGURE 6-7
GROSS AND NET NITROGEN DISCHARGES, BY REGION
HIGH GROWTH SCENARIO
1975, 1985, 2000

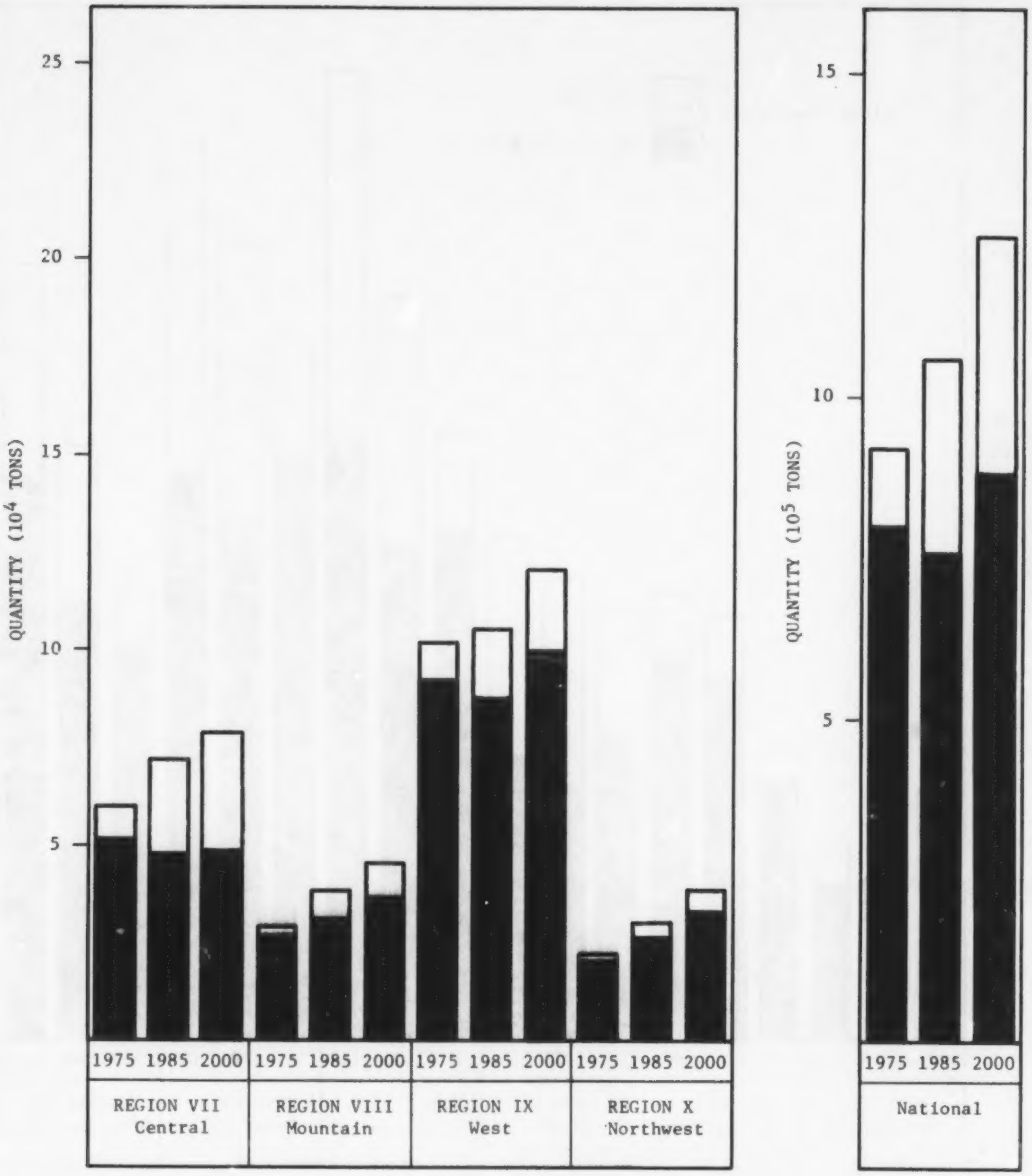

FIGURE 6-7
CONTINUED

Major industrial nitrogen dischargers in 1975 were the meat products processing, organic chemicals, and steel industries. However, coincidental removal of nitrogen is expected to considerably reduce the relative importance of these industries over the period, as shown in Figure 6-8. For example, in 1975, no coincidental removal of nitrogen occurred in the meat products processing industry. However, while the generation of nitrogen in wastes by meat products processing is expected to grow with industrial output (1.5 percent per year in the High Growth Scenario), net discharges to the environment are projected to decline substantially. Annual net discharges of nitrogen are projected to decline from the 1975 estimate of 90 thousand tons to approximately 15 thousand tons in 2000.

Methods used to meet the effluent limitations guidelines will probably vary within the meat products processing industry. For example, to remove nitrogen compounds from their wastewaters, meat packinghouses could use either an anaerobic contact system followed by aerobic stabilization ponds, or anaerobic-aerobic lagooning systems. Poultry processors could use one of three different biological treatments currently available--aerated lagoons, anaerobic-aerobic lagoons, or activated sludge.[35]

Reductions in nitrogen discharges in the Great Lakes and Central Regions (Federal Regions V and VIII) are expected from the meat products processing industry. In the Great Lakes Region, although the industry is expected to increase its dollar output by 1.3 percent per year over the 1975 to 2000 period, net discharges by the industry are projected in the High Growth Scenario to decline from 20 thousand tons in 1975 to under 2 thousand tons in 2000. In the Central Region (Federal Region VII), the meat products processing industry is projected to grow at the same rate as in the Great Lakes Region (Federal Region V), but net discharges would decline from 14 thousand tons in 1975 to 1 thousand tons annually in 2000 (High Growth Scenario).

Significant quantities of nitrogen are projected to be generated and discharged by the organic chemicals industry in both scenarios. Under High Growth, gross generation is projected to double, from almost 50 thousand tons in 1975 to about 100 thousand tons annually by 2000. Net discharges are also projected to double, increasing from about 30 thousand tons to 60 thousand tons annually in the same period. This increase in nitrogen discharges would result from the substantial growth in organic chemicals production projected in both scenarios and from the absence of any controls on nitrogen in wastewater.

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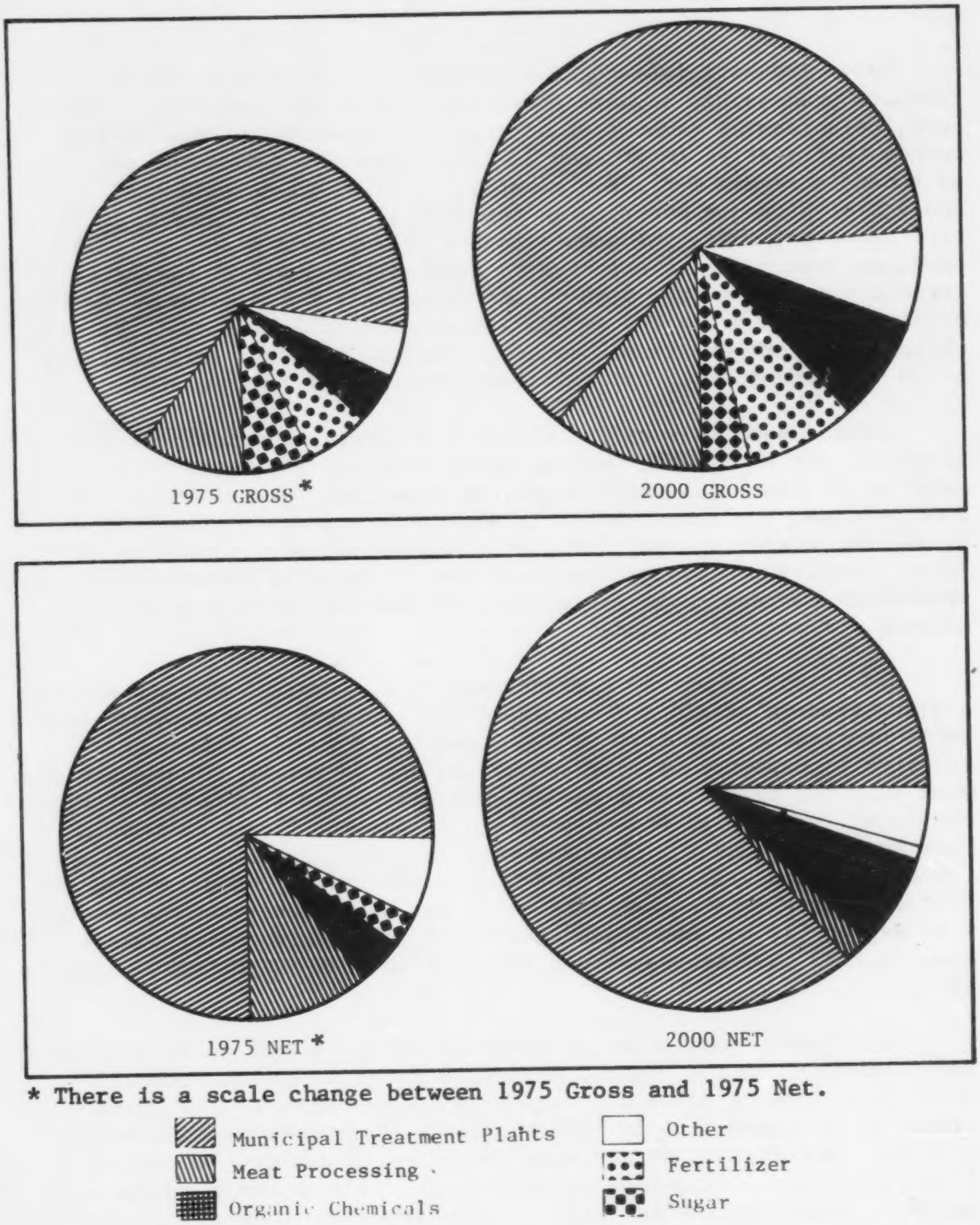
[35] Scaief, J.F., Effluent Variability in the Meat-Packing and Poultry Industries, Pacific Northwest Environmental Research Laboratory, Richland, Wa., June 1975.



* There is a scale change between 1975 Gross and 1975 Net.

FIGURE 6-8
GROSS AND NET DISCHARGES
OF NITROGEN, BY INDUSTRIAL GROUP
HIGH GROWTH SCENARIO
1975 AND 2000

The steel industry is expected to reduce its nitrogen discharges sharply over the projection period, primarily through process changes. An expected shift from open-hearth to basic oxygen and electric arc steelmaking would reduce net discharges of nitrogen from 24 thousand tons in 1975 to 1 thousand tons by 2000.

This process change in the steel industry would reduce nitrogen discharges in the Middle Atlantic Region (Federal Region III). Although industry output is expected to grow within the region, more than a 90 percent reduction of nitrogen produced by the industry is anticipated. This would reduce annual net discharges from 11 thousand tons in 1975 to less than 1 thousand tons in 2000 in both scenarios.

Overall, these trends in nitrogen discharges combine to produce large increases in discharges in Federal Regions IV and VI. The Southeast Region (Federal Region IV) is expected to experience the largest absolute increase in nitrogen generation over the period. Here, gross generation would increase from 150 thousand tons in 1975 to 250 thousand tons annually by 2000 (High Growth Scenario). Population growth, the main cause of this increase, would cause the gross influx of nitrogen to municipal treatment plants to increase from 100 thousand tons in 1975 to 140 thousand tons in 2000. Higher nitrogen loadings are also expected to result from a projected 3.2 percent annual increase in nitrate fertilizer production in Federal Region IV. Nitrate fertilizer production generated about 20 thousand tons of nitrogen as a pollutant in 1975 and is expected to generate about 35 thousand tons in 2000 in the High Growth Scenario. Increases in economic output by the meat products processing, organic chemicals, and steel industries are also expected to cause increased generation of nitrogen in Federal Region IV.

Federal Region IV was the second greatest regional source of net nitrogen discharges in 1975, and would become the major source in 2000 in the High Growth Scenario. Net discharges increase primarily because of the release of nitrogen from municipal treatment facilities and the organic chemicals industry.

The greatest absolute increase in net discharges of nitrogen is expected in the South Central Region (Federal Region VI). Here, the quantity of nitrogen released to surface waters is projected to increase from 100 thousand tons in 1975 to about 150 thousand tons in 2000. This is caused mainly by discharges from municipal sewage facilities, which alone would account for 75 thousand tons in 1975 and over 100 thousand tons in 2000. Net discharges of nitrogen in the region by the organic chemicals industry also are projected to increase between 1975 and 2000 in keeping with projected growth in the industry.

Relative to gross generation trends, increases in aggregate net discharges of nitrogen in Federal Region VI are moderated by the coincidental removal of nitrogen from the wastewaters of the meat products processing and fertilizer industries. While gross generation increases by 70 percent over the projection period in the region, net discharges of nitrogen are expected to increase by only 40 percent in the High Growth Scenario.

6.2.6 Phosphorus

HIGHLIGHTS OF SECTION 6.2.6

- In its elemental form, phosphorus is toxic to fish life. As phosphate, it can contribute to algal blooms.
- Municipal treatment plants are by far the greatest point source of phosphorus.
- The generation of phosphorus is projected to increase slightly and net discharges to decline slightly under high economic growth conditions between 1975 and 2000.
- Regional trends in phosphorus discharges follow, for the most part, regional population trends, with exceptions in the New York-New Jersey Region (Federal Region II) and the West Region (Federal Region IX).

Introduction

Phosphorus can be found in two basic forms. The first form, elemental phosphorus, is particularly toxic to animal and plant life and is subject to bioaccumulation in much the same way as mercury and other toxic metals. Fish can concentrate elemental phosphorus from water containing as little as 1 milligram per liter. Experimental findings have shown that phosphorus is stable in fish, accumulating in muscles, fatty tissues, and the liver.[36]

The second form of phosphorus, phosphates, is one of the major nutrients required by plants. In excess of critical concentrations, phosphates can stimulate algal growth in receiving waters. Phosphates are frequently the nutrients in shortest supply in fresh waters, so that an increase in phosphates may allow algae and other plants to grow excessively. Overabundance of algae in lakes and streams causes objectionable odors and may interfere with fishing, water contact recreation, and water supply.

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[36] U.S. Environmental Protection Agency, Office of Water & Hazardous Materials, Quality Criteria for Water, Washington, D.C., July 1976, p. 188.

The SEAS estimates discussed in the following section include both forms of phosphorus, though they are not distinguished in the text. Rather, projections of total phosphorus in wastewater discharges, composed of elemental phosphorus plus the phosphorus component (by weight) of the phosphate radical, are examined below.

Discharge Trends for Phosphorus

General Trends. Gross generation of phosphorus is expected to increase by about one-half percent per year from 1975 to 2000, from 350 thousand tons in 1975 to just over 400 thousand tons annually by 2000 in the High Growth Scenario. In the Low Growth Scenario, a very slight increase over the 1975 level is expected by 2000.

Net discharges of phosphorus, in contrast, are expected to decline from 1975 to 2000 in both scenarios. From almost 300 thousand tons in 1975, net discharges are expected to fall by 20 percent in the High Growth Scenario to 220 thousand tons annually by 2000. This is attributable to compliance with effluent limitations guidelines by industrial and municipal sources over the 1975 to 1985 period, assumed in the SEAS model. By 1985, net discharges are projected to be 30 percent less than the 1975 level in the High Growth Scenario. Between 1985 and 2000, net discharges of phosphorus again would increase slightly (by 8 percent) as no further regulations limiting phosphorous discharges are assumed in either scenario.

As with most of the other conventional pollutants, the modeling assumption of full compliance with effluent limitations guidelines affects forecasted trends in net discharges. An intermediate level of discharges, one assuming that abatement efficiencies in the future do not improve over those in 1975, provides a "worst case" scenario in terms of abatement. The resulting intermediate discharge levels, as well as gross generation and net discharges, are shown in Figure 6-9 for 1975, 1985, and 2000 in the High Growth Scenario by region and for the nation. Because the major sources of discharges are municipal sewage treatment facilities, the regional distribution of phosphorus discharges follows the population distribution, and is thus very similar to the nitrogen discharge pattern shown earlier in Figure 6-7.

Analysis of Trends. Municipal sewage treatment is by far the most significant point source of phosphorus, so overall trends in phosphorus discharges follow trends in discharges from this source. For example, between 1975 and 1985, net discharges of phosphorus from municipal treatment facilities are projected to decline from 250

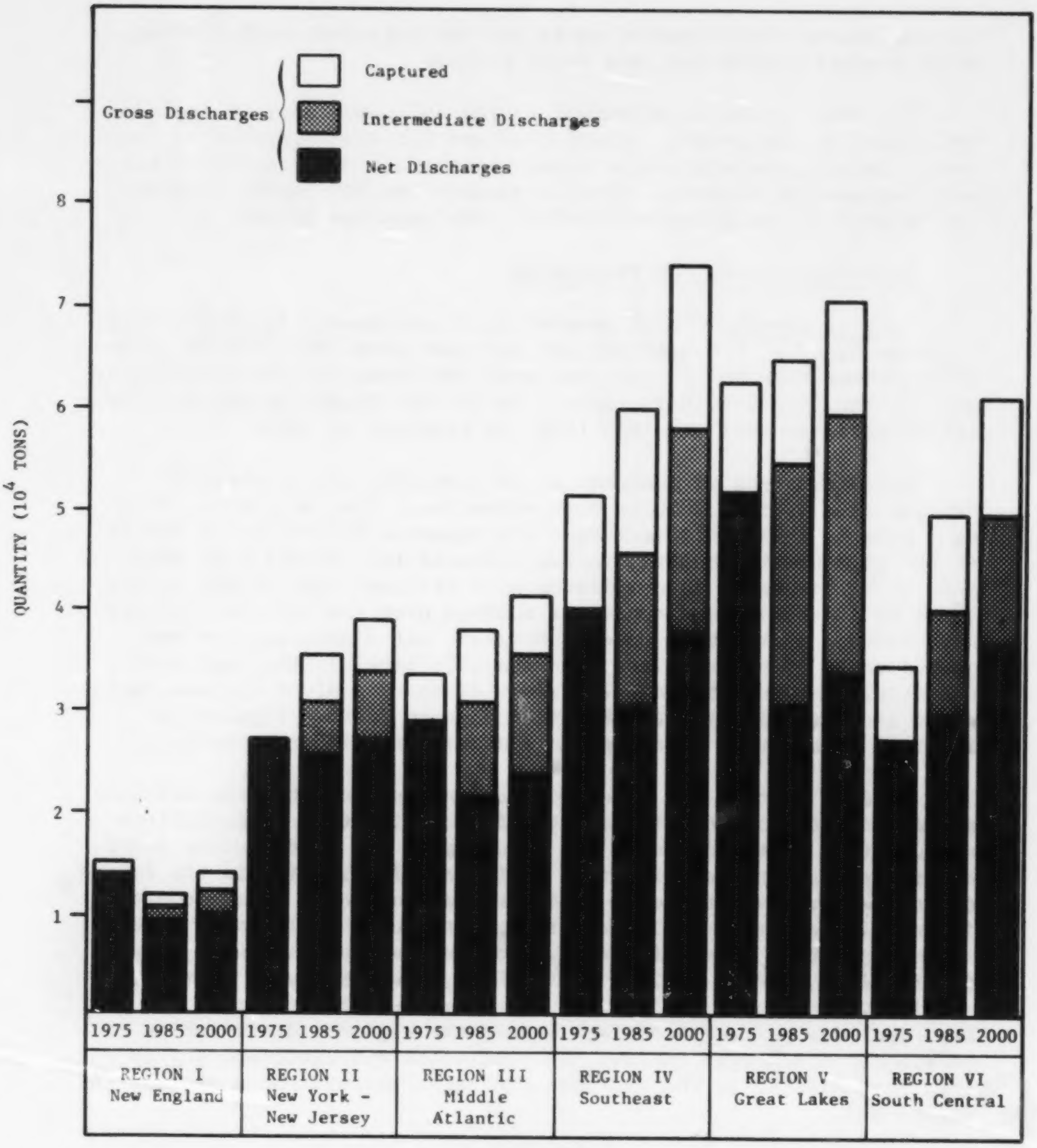

FIGURE 6-9
GROSS, INTERMEDIATE, AND NET PHOSPHORUS DISCHARGES, BY REGION
HIGH GROWTH SCENARIO
1975, 1985, 2000

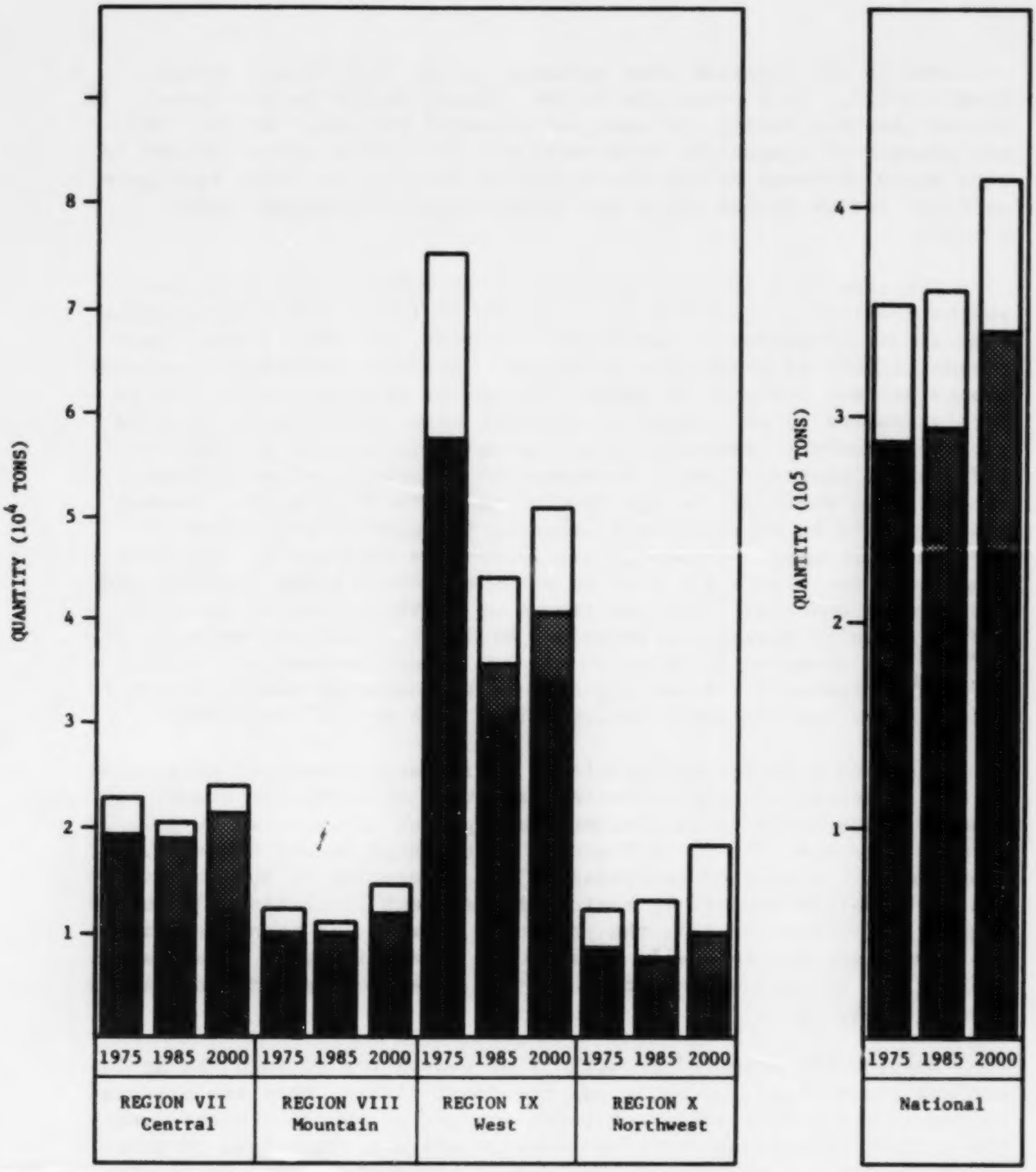

FIGURE 6-9
CONTINUED

thousand to 200 thousand tons annually in the High Growth Scenario (Table 6-12). This reduction is the primary factor in the overall 30 percent decline during the same period noted earlier. Beyond 1985, net phosphorus discharges from municipal facilities are projected to once again increase to 220 thousand tons annually by 2000; aggregate national trends follow the trend in municipal discharges almost exactly.

The reduction in net discharges of phosphorus from municipal sewage facilities is attributable to two factors: the coincidential removal of phosphorus in secondary treatment, and anticipated lower concentrations of phosphorus in sewage. Although secondary treatment plants are not designed to remove phosphorus from wastewater, it is partly removed in the course of removing other pollutants. Institution of secondary treatment by all municipalities over the 1975 to 1985 period therefore would increase the percentage of phosphorus removed from municipal sewage from about 20 to 30 percent. Greater removal could be achieved with existing (secondary) facilities if particular processes currently available were instituted. In these processes, coagulants are used to cause solids to clump together and settle more quickly. This can remove up to 90 percent of the phosphorus normally present in secondary effluent. SEAS estimates do not reflect the adoption of these processes, since improvements beyond secondary treatment are not expected on a widespread basis, except in waters under international jurisdiction, such as the Great Lakes.

The second factor influencing net discharge trends of phosphorus is its concentration in wastewaters arriving at sewage treatment plants. Phosphorus in wastewaters is expected to increase by only 7 percent over the 1975 to 2000 period in the High Growth Scenario. Compared with projected increases in the generation of BOD and nitrogen that must be treated by municipal treatment facilities (30 and 40 percent over 1975 levels), the projected increase in phosphorus in raw sewage streams is small. This would be attributable to a gradual phasing out of most detergents and other domestic products containing phosphates by 1985.

Despite the expected reductions of phosphorus in both the influent and the effluent of municipal treatment plants, they are expected to remain the most significant point sources of this pollutant over the period, accounting for 95 percent of all net discharges of phosphorus by 2000 in the High Growth Scenario (compared with 86 percent in 1975) as indicated in Table 6-12.

The largest industrial source of phosphorus discharges (see Table 6-12) is the meat products processing industry. In 1975, it was estimated that over 20 thousand tons of phosphorus were released to the environment by this industry. About half of this came from

TABLE 6-12
PROJECTED DISCHARGES OF PHOSPHORUS BY MAJOR SOURCES
HIGH GROWTH SCENARIO
1975, 1985, 2000
(THOUSANDS OF TONS)

Source	1975				1985				2000			
			Percent of Total				Percent of Total				Percent of Total	
	Gross	Net	Gross	Net	Gross	Net	Gross	Net	Gross	Net	Gross	Net
Municipal Wastewater Treatment Facilities	310	250	89	86	300	200	83	95	330	220	80	95
Meat Processing	20	20	6	8	25	4	7	2	30	6	8	2
Inorganic Chemicals	9	1	3	<1	14	<1	4	<1	20	<1	4	<1
Electric Utilities	9	9	3	3	13	1	4	1	20	2	4	1
Other	7	7	2	2	7	5	2	2	16	3	4	2
Total[a]	350	290	100	100	360	210	100	100	410	230	100	100

[a] Rounding may create inconsistencies in addition.

packinghouses, with poultry processing and slaughterhouses adding 3 thousand tons each. However, this is expected to change over the next decade. While gross generation is projected in the High Growth Scenario to increase by 45 percent over the 1975 level by 2000, compliance with BAT standards would reduce net discharges of phosphorus from the meat products processing industry by 75 percent. Removal of phosphorus is expected to be particularly effective in the poultry processing and the slaughterhouse industries; these industries are projected to remove 90 and 95 percent of phosphorus from their wastewaters.

Because municipal treatment facilities are the predominant source of phosphorus, regional discharge trends follow regional population trends. Generally, regions where population is expected to increase faster than the national average are expected to achieve less than the average reduction in phosphorus discharges. However, there are three exceptions to this generalization: the New York-New Jersey, Great Lakes, and West Regions (Federal Regions II, V, and IX).

In the New York-New Jersey Region (Federal Region II), gross generation of phosphorus is expected to increase more than 40 percent between 1975 and 2000, from 27 thousand tons to 40 thousand tons annually in the High Growth Scenario. This is double the projected national increase (18 percent) in phosphorus generation. Since the population in Federal Region II is expected to increase only 8 percent by 2000, the explanation for this extraordinary rise in phosphorus generation must lie in factors other than population. The Federal Construction Grants Program may be the source. Out of an estimated $15 billion investment for municipalities to achieve secondary treatment, nearly $3.5 billion is to be invested in Federal Region II. This is expected to increase the amount of sewage treated in the region by 40 percent during the 1975 to 2000 period, and this would mean an increase in the amount of phosphorus entering municipal treatment plants. Large new quantities of phosphorus therefore would come from homes which were previously unsewered or served by inadequate treatment plants. Thus, extraordinary increases in gross phosphorus in Federal Region II are not resulting solely from actual increases in the amount of phosphorus produced as waste in the region, but from the transfer of phosphorus in the form of a non-point source pollutant (septage) to a point source pollutant (municipal wastewater) in the SEAS accounting system.

Net discharges of phosphorus in Federal Region II are expected to increase at a slower rate than gross generation. By 2000, annual net discharges are projected in the High Growth Scenario to be only 20 percent greater than 1975 discharge estimates, because of the anticipated removal of some phosphorus from municipal effluents. In

1975, only 20 percent of the phosphorus was removed from wastewaters in Federal Region II. However, because more secondary treatment plants will come on-line, by 2000 more than 40 percent of the phosphorus is expected to be removed from municipal wastewaters prior to discharge.

Discharges of phosphorus in the Great Lakes Region (Federal Region V) are expected to decline faster than national projections because of special circumstances which are occurring in the Great Lakes Basin. A goal has been set by international agreement, that all municipal sewage plants which treat more than 1 million gallons of wastewater per day are required to reduce phosphorus concentrations to 1 mg/l. This reduces phosphorus loadings significantly compared to coincidental reductions achieved in other parts of the country. It should be noted that additional phosphorus load reductions for the Great Lakes Basin are currently being considered by the parties to the International Joint Commission on the Great Lakes.[37]

Discharges of phosphorus within the West Region (Federal Region IX) are projected to decline in both scenarios, despite an expected 30 percent increase in population by 2000. This is attributable to two anticipated improvements: the reduction in phosphorus concentration in municipal wastewaters and a higher degree of phosphorus removal from wastestreams of the meat products processing industry.

The Southeast Region (Federal Region IV) is expected to experience a 40 percent increase in phosphorus generation between 1975 and 2000, attributable primarily to regional population growth approaching 40 percent over the period. Increases in economic output from the inorganic chemicals and meat products processing industries are also expected to result in the generation of greater quantities of phosphorus. Despite these rather large increases in phosphorus generation, net discharges of phosphorus are expected to decline slightly between 1975 and 2000, because of effective treatment of phosphorus in the wastewaters of the inorganic chemicals and meat products processing industries. Increases in net discharges from municipal sewage treatment plants are expected to partially offset industrial improvements, however.

The greatest regional increase in discharges of phosphorus is expected in the South Central Region (Federal Region VI). Gross generation is projected in the High Growth Scenario to increase from 35 thousand tons in 1975 to above 60 thousand tons in 2000, a 2.3

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[37] Personal communication, Francis T. Mayo, Director of the Municipal Environmental Research Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio, September 6, 1979.

percent per year growth rate. Net discharges are expected to increase more slowly, about 1 percent per year. A projected 1.2 percent annual increase in population is the principal reason for the increases, as sewage influent accounts for over 80 percent of the gross phosphorus generation and 95 percent of the net point discharges in Federal Region VI.

While phosphorus discharges would increase in Federal Region II despite less than average population growth, phosphorus discharges are projected to decline in the West Region (Federal Region IX) despite an expected 30 percent increase in population between 1975 and 2000. A projected decline of 30 percent gross loadings of phosphorus between 1975 and 2000 is attributable primarily to a reduction in phosphorus entering municipal treatment plants. Net discharges of phosphorus are expected to decline at an even higher rate (40 percent from the 1975 level) than gross generation because of increased removal of phosphorus by municipal treatment plants and the expected removal of phosphorus from the wastestreams of the meat processing industry.

6.2.7 Oil and Grease

HIGHLIGHTS OF SECTION 6.2.7

- The oil and grease pollutant category includes thousands of organic compounds. It is a concern primarily because of its toxicity to aquatic organisms, its input to BOD, and its capacity for fouling shorelines and beaches.

- Gross generation of oil and grease as a pollutant is expected to increase from 1.2 to 1.9 million tons between 1975 and 2000 under high economic growth conditions, while net discharges are expected to decline 30 percent from their 1975 levels--from 480 thousand tons to 340 thousand tons.

- The meat processing industry is expected to generate the most oil and grease throughout the 1975 to 2000 period, but the major net discharger is expected to be petroleum refining and storage. Oil and grease compounds emanating from petroleum industries are potentially more harmful than natural oil and grease from meat processing.

- Due to the continued development of Alaskan oil, the Northwest Region (Federal Region X) is expected to have the most notable increase in discharges of oil and grease.

Introduction

Oil and grease is a pollutant category that comprises thousands of organic compounds with varying physical, chemical, and toxicological properties. It includes hydrocarbons, fatty acids, soaps, waxes, and oils. These substances are difficult to discuss generally since they may be volatile or nonvolatile, soluble or insoluble, persistent or easily degradable.

Oily wastes may be classified as follows:

- Light hydrocarbons: These include light fuels, such as gasoline, kerosene, and jet fuel, and miscellaneous solvents used for industrial processing, degreasing, or cleaning purposes. The presence of these light hydrocarbons may make the removal of other oily wastes more difficult.
- Heavy hydrocarbons, fuels, and tars: These include the crude oils, diesel oils, No. 6 fuel oils, residual oils, slop oils, and, in some cases, asphalt and road tar.
- Lubricants and cutting fluids: These generally fall into two classes--non-emulsifiable oils such as water soluble oils, rolling oils, cutting oils, and drawing compounds and emulsifiable oils containing fat, soap, or various other additives.
- Vegetable and animal fats and oils: These originate primarily from processing of foods and natural products.

Oil and grease are found in process wastewater from washdown, runoff, spills, and leakage. Because of widespread use, they are common in wastewater streams. Field and laboratory evidence has shown both acute toxicity and sublethal toxicity of oils to aquatic organisms.[38] Oil and grease of any kind in the water can be detrimental to fish and waterfowl, increase BOD in the water, and foul shorelines and beaches. The discussion that follows estimates trends in point discharges of oil and grease, including spills.

Discharge Trends for Oil and Grease

General Trends. Gross generation of oil and grease is expected to increase by almost 2 percent per year over the 1975 to 2000 period in the High Growth Scenario. From an estimated 1.2 million tons in 1975, the projections indicate that gross generation will be 1.9 million tons by 2000.

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[38] Hampson, G.R. and H.L. Sanders. "Local Oilspills," Oceanics, Vol. 15, 1969.

In contrast, both scenarios forecast a decline in net discharges of oil and grease between 1975 and 2000. From a 1975 estimate of almost 500 thousand tons, net discharges are projected in the High Growth Scenario to decline at an annual rate of almost 1.5 percent to 340 thousand tons by 2000. Oil and grease discharges would decline in the Low Growth Scenario by 2.3 percent during the same period. These declines would be attributable to anticipated compliance with BAT standards for oil and grease by most major industrial sources. The meat products processing, steel, and textile industries are expected to achieve significant reductions in their discharges of oil and grease between 1975 and 1985. In this period, total annual net discharges are projected in the High Growth Scenario to decline by 50 percent. Beyond 1985, however, no further restrictions on oil and grease discharges are expected to be introduced.

The regional distribution of gross, intermediate, and net discharges of oil and grease is shown in Figure 6-10. Should compliance with effluent limitations guidelines lag behind schedule, discharges could be greater than suggested by the net discharge estimates. This applies particularly to the Great Lakes Region (Federal Region V) where the SEAS assumption that the steel industry would remove significant amounts of oil and grease from its wastewaters is crucial to the net discharge estimate.

Analysis of Trends. The meat products processing industry is expected to be the largest generator of oil and grease through 2000 (Figure 6-11). It is estimated that, in 1975, about 400 thousand tons of oil and grease were generated by the meat products processing industry, one-third of all point source generation. This proportion is expected to remain constant. Packinghouses are expected to be responsible for two-thirds of the meat products processing industry's total generation.

Although large quantities of oil and grease would be generated, the meat products processing industry is expected to control this pollutant throughout the 1975 to 2000 period. Net discharges of oil and grease from the industry in 1975 are estimated at 350 thousand tons (30 percent of gross generation). By the year 2000, it is anticipated that full compliance with BAT standards would reduce the oil and grease discharged to the environment to as little as 2 percent of the amount generated as waste. Particularly effective removal is expected at packinghouses. Gross generation of oil and grease by packinghouses is projected to be 360 thousand tons in 2000; net discharges are expected to be only 5 thousand tons.

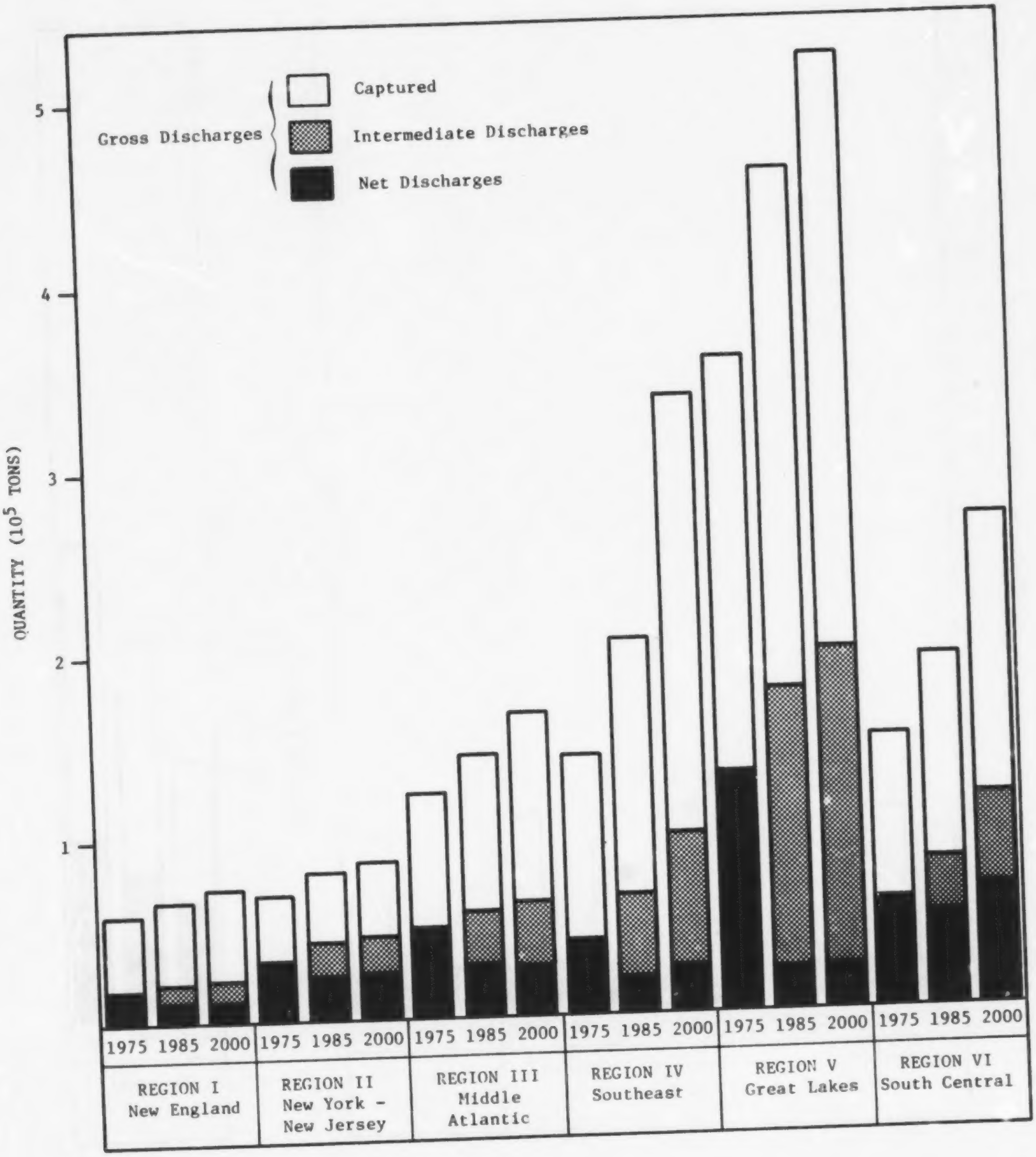


FIGURE 6-10
GROSS, INTERMEDIATE, AND NET OILS AND GREASE DISCHARGES, BY REGION
HIGH GROWTH SCENARIO
1975, 1985, 2000

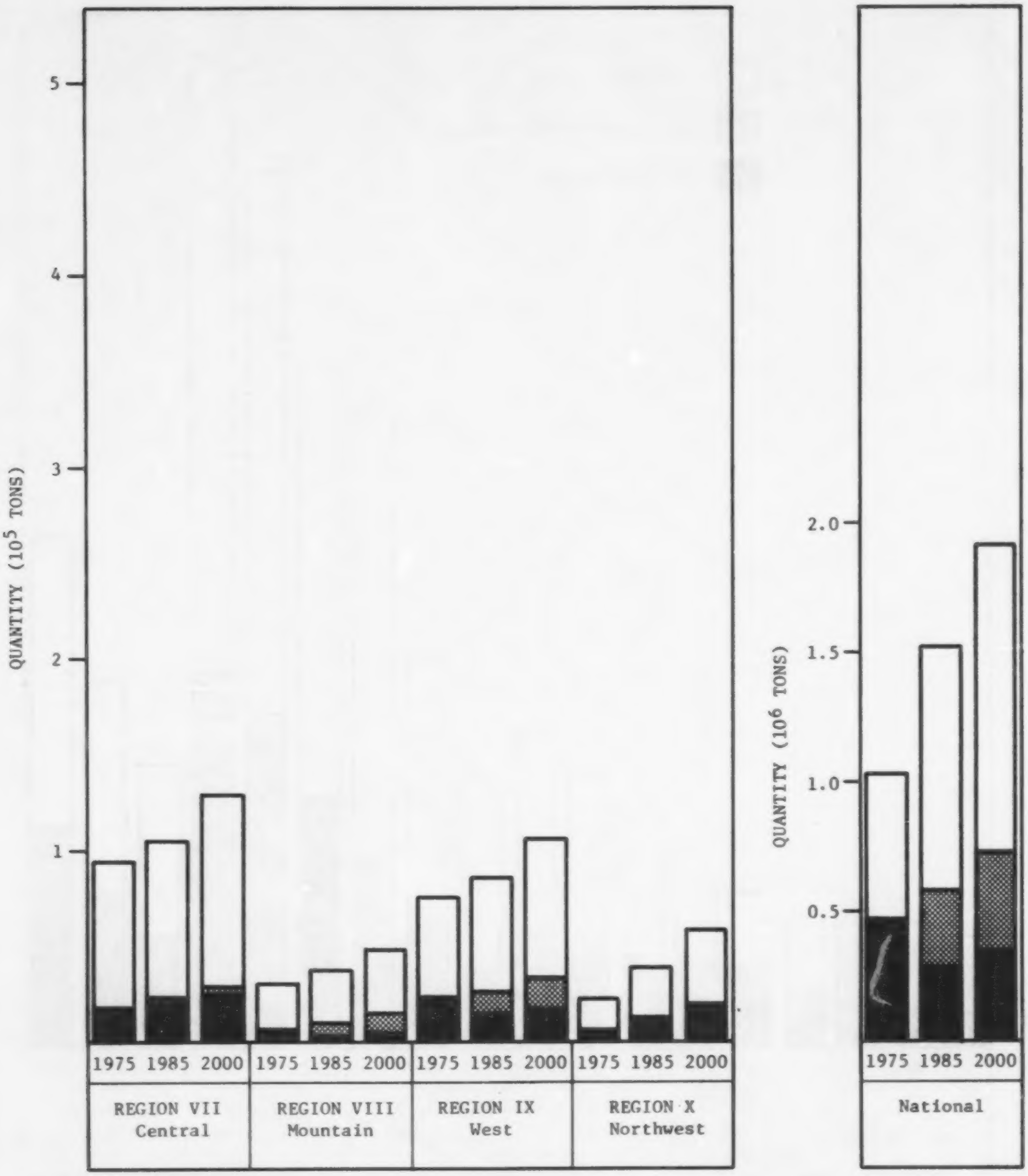
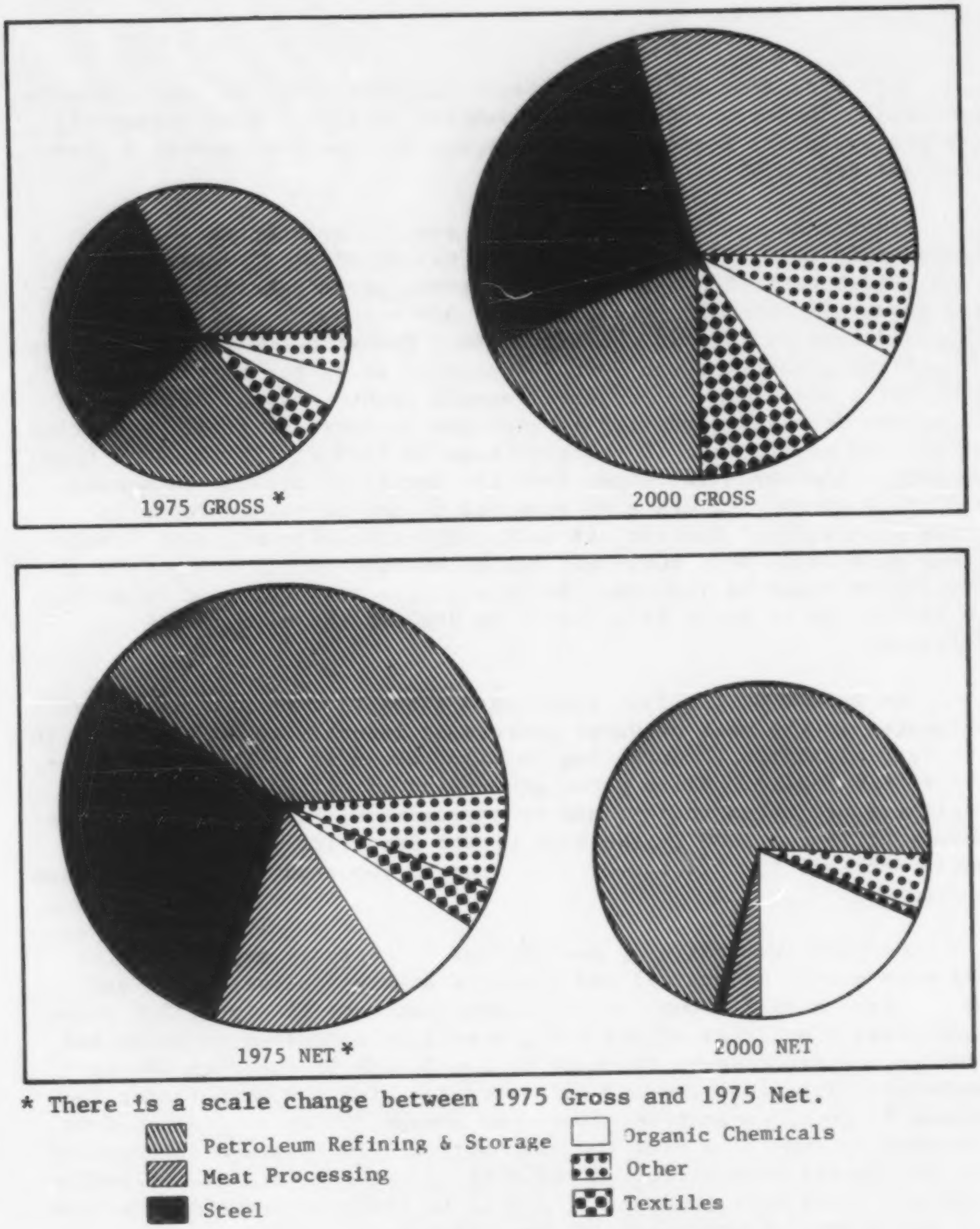


FIGURE 6-10
CONTINUED



* There is a scale change between 1975 Gross and 1975 Net.

FIGURE 6-11
GROSS AND NET DISCHARGES
OF OIL AND GREASE, BY INDUSTRY GROUP
HIGH GROWTH SCENARIO
1975 AND 2000

This reduction in oil and grease discharges by the meat products processing industry would benefit several regions. Most noteworthy are the Southeast Region (Federal Region IV) and the Central Region (Federal Region VII).

Federal Region IV is expected to see the greatest absolute increase in the generation of oil and grease of any Federal Region. From a 1975 estimate of 140 thousand tons, gross generation of oil and grease is expected to increase by 3.6 percent per year to 340 thousand tons by 2000 in the High Growth Scenario. The major source of oil and grease through 2000 is expected to be the meat products processing industry. A projected annual growth rate of 2.5 percent in output from that industry is expected to increase gross generation of oil and grease from 70 thousand tons in 1975 to 125 thousand tons by 2000. Increases in output from the textiles, organic chemicals, and steel industries are also expected to add to the increase in gross generation. However, if full compliance with effluent limitations guidelines were achieved, net discharges of oil and grease in the region would be reduced. Net discharges are projected to decline to two-thirds of their 1975 levels by 2000 in the High Growth Scenario.

The effect of the full compliance assumption on oil and grease estimates in the meat products processing industry is most obvious in the Central Region (Federal Region VII), where it is the major industry of the region. While gross generation of oil and grease in the region is projected to increase by approximately 1.5 percent per year between 1975 and 2000 in the High Growth Scenario, net discharges would decrease by a factor of six, from 18 thousand tons to less than 3 thousand.

The petroleum refining and storage industry is expected to be the main source of net oil and grease discharges between 1975 and 2000. From a 1975 annual net discharge estimate of almost 200 thousand tons, discharges of oil and grease from petroleum refining and storage are expected to increase by one-fourth in the High Growth Scenario. This increase may be contrasted with the much faster increase in gross generation of oil and grease, which is projected to increase by one-third over the same period. Increased discharges of oil and grease from petroleum refining and storage are of particular concern, since they are more likely to be toxic to aquatic life than oil and grease discharges from other sources.

Treatment is expected to achieve 95 percent removal of oil and grease from the petroleum refining industry's wastewaters by 1985. As a result, net discharges from petroleum refining processes are projected to account for less than 1 percent of all net discharges from point sources by the year 2000, even though they still would account for 40 percent of all oil and grease generated.

Oil and grease discharges from storage and transportation operations in the industry are more difficult to control than wastewater. Spills and leaks during transportation of crude oil and petroleum products and from the storage of oil products are expected to increase gradually as these activities grow. Between 1975 and 2000, it is expected that spills and leaks of oil and grease will increase from almost 200 thousand tons to 220 thousand tons annually in the High Growth Scenario.

Trends in oil and grease discharges in the Northwest Region (Federal Region X) would reflect continued exploitation of the Alaskan oil fields. Total constant dollar output in the petroleum refining and storage industry in Federal Region X is expected in the High Growth Scenario to grow from $550 million in 1975 to nearly $2 billion in 2000. As a result, net discharges of oil and grease from petroleum refining and storage there are projected to increase at an annual rate of 7 percent between 1975 and 2000 in the High Growth Scenario.

Over the 1975 to 2000 period, annual production of Alaskan oil is projected in both scenarios to increase from about 70 million barrels to more than 1 billion barrels. Leaks and spills from the trans-Alaska pipeline are likely to be greater than the national average because of the 135°F temperature of the oil being transported and the permanently frozen subsoils over which it travels.[39] Further, spills also can be expected from terminal operations.

Increased production of Alaskan oil can be expected to affect discharges of oil and grease from petroleum refining in the West Region (Federal Region IX) as well. Most of the oil from the Alaskan fields is expected to be refined in California, and as a result, annual gross production of oil and grease wastes in petroleum refining and storage in Federal Region IX are projected to increase by 1 percent per year in both scenarios between 1975 and 2000. However, most of this waste is attributable to petroleum refining, which will remove most oil and grease from its wastewaters prior to discharge. Thus, net discharges are projected to increase at only half a percent per year between 1975 and 2000. Trends in gross generation of oil and grease from other industries in Federal Region IX are expected to lag behind national trends since economic growth in the major industrial sources is projected to be lower in Federal Region IX than nationally. Furthermore, compliance with effluent limitations guidelines in major industrial categories is expected in the High Growth Scenario to result in a 30 percent reduction of net discharges of oil and grease by 2000.

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[39] Council on Environmental Quality, Energy Alternatives: A Comparative Analysis, U.S. Government Printing Office, Washington, D.C., May 1975, p. 3-37.

Generation of waste oil and grease by the steel industry is expected to increase by over 50 percent from 1975 to 2000. This follows directly from the increase in economic output expected in the industry during that period. However, the anticipated shift away from open hearth steelmaking and assumed compliance with effluent limitations guidelines for oil and grease would curtail net discharges. It is estimated that about 150 thousand tons of oil and grease were discharged to the environment by the steel industry in 1975. This would decline to only 2 thousand tons by 2000 in the High Growth Scenario.

The organic chemicals industry is projected to generate greater quantities of oil and grease over the 1975 to 2000 period. From a 1975 estimate of around 50 thousand tons, oil and grease wastes are projected in the High Growth Scenario to increase at an annual rate of 2.5 percent. This increase is most evident in the production of phenols and acetones where gross oil and grease wastes are expected to increase at an annual rate of 4.5 percent. Net discharges of oil and grease by the organic chemicals industry are expected to increase from under 40 thousand to around 70 thousand tons between 1975 and 2000 in the High Growth Scenario. Although increased control of discharges of oil and grease is assumed in our projections, a projected annual increase in economic output of almost 5 percent for the industry is expected to more than offset these control improvements.

The Great Lakes Region (Federal Region V) generated approximately 30 percent of the national total of oil and grease wastes in 1975, more than twice that of any other region. However, the region's share of the national total is expected to decline over the 1975 to 2000 period because of assumed effluent controls by the steelmaking industry. Gross generation of oil and grease wastes is projected in the High Growth Scenario to increase from 350 thousand tons in 1975 to over 500 thousand tons in 2000. This increase is attributable to an expected 13 percent increase in output by the meat products processing industry and a 50 percent increase in steel manufacturing. However, steel is expected to remove 99 percent of all oil and grease from its wastestreams by 1985. Net discharges of oil and grease in the region would therefore decline by 65 percent by 2000.

The South Central Region (Federal Region VI) is projected to experience increased discharges of oil and grease in the High Growth Scenario only. Gross generation of oil and grease wastes is expected to increase by 2.5 percent annually, from 150 thousand to 270 thousand tons in this scenario. This would be attributable to a projected threefold increase in economic output by the organic chemicals industry and a 70 percent increase in output from the meat products processing industry in the region. However, net discharges of oil and grease are projected to increase by only 10 percent over the 1975 estimate. In the Low Growth Scenario, net discharges are expected to decline by 10 percent. This difference between scenarios is due primarily to different growth rates that would be achieved by the organic chemicals industry in the region under high and low economic growth conditions. Although full compliance with BAT standards would greatly reduce the net discharges of oil and grease by most industries, the organic chemicals industry is expected to more than double its discharges in any case.

6.2.8 Toxics and Other Pollutants

HIGHLIGHTS OF SECTION 6.2.8

- Gross generation of cadmium, chromium, cyanide, and copper is expected to increase, and the generation of mercury to decrease between 1975 and 2000. Generation of phenol (as oil and grease) is expected to increase while phenol (as dissolved solids) is expected to decline over the same time period. Net discharges of all the analyzed toxics are expected to decline substantially between 1975 and 2000, because of environmental controls.

- Chemical oxygen demand (COD) generation is expected to increase substantially between 1975 and 2000, but net discharges are expected to decline slightly. Organic chemicals manufacture and electric utilities are expected to be the major sources of COD discharges.

- While the number of fecal coliform bacteria in observed stream segments has declined recently, primarily because of improved treatment of sewage by municipalities, this pollutant still poses a widespread water quality problem.

Toxic Metals and Phenols

Toxic substances in water bodies are of considerable concern because of their potential effects on human health and aquatic ecosystems. Even low concentrations of some toxics can cause tumors, mutations, and developmental effects on animal and plant populations that depend upon polluted water sources. Because concern about toxic chemicals has developed only recently, few data are available for use in projecting discharge trends. This is particularly evident for toxic organic chemicals. Consequently, SEAS toxic pollution estimates are fragmentary and cover only a small fraction of the 65 classes of toxic pollutants already recognized by EPA.[40] Also, toxic substances may appear in water from either direct deposition from the atmosphere or leaching from soils and rocks by acid precipitation.

Lack of alternative data sources makes it difficult to assess the accuracy of the current SEAS toxics data base. However, comparison with data collected by EPA's Effluent Guidelines Division on the occurrence of toxic pollutants (primarily metals) in industrial wastewaters shows SEAS industrial coverage to be most complete for cadmium, chromium, copper, cyanide, mercury, and phenol. These are the toxics dealt with in this section. The SEAS-generated trends should, however, be interpreted with caution.

Toxic metals have also been found in samples from remote, "pristine" areas. This raises the concern for their direct deposition or mobilization by acid precipitation. Toxic metals are often found in surface waters near industrial areas.[41] They persist in sediments and are not degraded by biological action. In fact, toxic metals may become concentrated in the tissues of predatory wildlife species.

The toxicity of cyanide arises from its capability to inhibit cellular metabolism. Cyanide compounds vary in their persistence; their widespread use by industry makes cyanide pollution a potentially serious problem in most of the United States.

The toxicity of phenol depends somewhat on other conditions in the water. Low dissolved oxygen concentrations, increased salinity, and higher temperatures all increase its toxicity. Phenolic compounds also can taint fish caught in polluted waters and degrade the taste of drinking water. Phenols are difficult to remove from drinking water supplies--a matter of concern because they have been found to be carcinogenic in mice. The health effects of the toxic substances discussed in this section are summarized in Table 6-13.

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[40] National Resources Defense Council v. Train, No. 75-172, S.R.C. 2120 (D.D.C. June 9, 1976). Toxic metals discharged to water estimated by SEAS are antimony, arsenic, asbestsos, cadmium, chromium, copper, cyanide, lead, mercury, nickel, phenol, selenium, and zinc. SEAS also estimates phenol and cyanide discharges.

[41] Council on Environmental Quality, Environmental Quality, U.S. Government Printing Office, Washington, D.C., December 1978, p. 131.

TABLE 6-13
THRESHOLD LIMITS AND EFFECTS OF SELECTED TOXIC POLLUTANTS

Pollutant	Threshold[a]	Effects
Cadmium	10 ug/l for domestic water supply Fresh Water 0.4 ug/l - 1.2 ug/l for cladocerans and salmonid fishes. 4 ug/l - 12.0 ug/l for other, less sensitive aquatic life. Maine 5.0 ug/l.	Itai-itai disease,[b] chronic kidney disease,[c] cadmiosis
Chromium	50 ug/l for domestic water supply. 100 ug/l for freshwater aquatic life.	Corrosive ulcers, scars, non-ulcerative contact dermatitis, eczematoris, noneczematous contact dermatitis[d]
Copper	1.0 mg/l for domestic water supplies. For marine and aquatic life, 0.1 times a 96-hour LC_{50}	Acute toxicosis, chronic toxicosis, Wilson's Disease, Cholestosis[e]
Cyanide	5.0 ug/l for freshwater and marine aquatic life and wildlife.	Direct toxicity affecting respiration[f]
Mercury	2.0 ug/l for domestic water supply. 0.05 ug/l for freshwater aquatic life and wildlife. 0.10 ug/l for marine aquatic life	Organomercurials, pharyngitis, gastroenteritis, ulcerative hemorrhagic colitis, hepatitis[g]
Phenol	1 ug/l for domestic water supply and to protect against freshwater tainting	Irritant causing burns, tumor promoter in presence of some chemicals.[h]

ug/l = micrograms per liter

[a] U.S. Environmental Protection Agency, Office of Water and Hazardous Materials, Quality Criteria for Water, Washington, D.C., July 1976.

[b] Kobayashi, J., "Relation Between 'Itai-Itai' Disease and the Pollution of River Waters," Fifth International Water Pollution Research Conference, I-15, 1-7, 1970.

[c] Friberg, L. et al, "Cadmium Poisoning," Journal of the American Medical Association, Vol. 17, 1974, p. 86.

[d] National Academy of Sciences, Medical and Biological Effects of Environmental Pollutants: Chromium, Washington, D.C., 1974.

[e] National Academy of Sciences, Medical and Biological Effects of Environmental Pollutants: Copper, Washington, D.C., 1977.

[f] Personal communication, Jim Darr, U.S. Environmental Protection Agency, Office of Toxic Substances.

[g] National Academy of Sciences, An Assessment of Mercury in the Environment, Washington, D.C., 1977.

[h] National Institute of Occupational Safety and Health, Criteria for a Recommended Standard Exposure to Phenol, Washington, D.C., July 1976.

This section summarizes projections of toxic pollutant discharges from point sources as estimated by SEAS. Where applicable, special attention is given to the discharges from five major chemicals. These industries are emphasized because their discharge data are considered to be the most reliable. Table 6-14 summarizes trends in discharges of the six toxics to be examined.

Cadmium. Generation of cadmium wastes is projected to increase from about 400 tons in 1975 to 1,000 tons annually by 2000 in the High Growth Scenario and to about 850 tons in the Low Growth Scenario--annual growth rates of 3.7 and 3 percent.

Assumed compliance with effluent limitations guidelines (BAT) by 1985 would reduce cadmium discharges significantly over the 1975 to 2000 period. Net discharges in 1975 are estimated to have been about 75 tons, but by 2000 in the High Growth Scenario, discharges are projected to decline to 17 tons annually (13 tons in the Low Growth Scenario). Only the organic chemicals and other nonferrous metals industries are projected by SEAS to release significant quantities of cadmium after 1985, since the electroplating industry, a major source at present, would reduce its discharges to zero through full compliance with BAT. A regional breakdown indicates that the New York-New Jersey, Southeast, Great Lakes, and South Central Regions (Federal Regions II, IV, V, and VI) are expected to be the major areas of cadmium waste generation.

The regional distribution of cadmium generation is largely determined by the location of the electroplating industry. A regional breakdown indicates that the New York-New Jersey, Southeast, Great Lakes, and South Central Regions (Federal Regions II, IV, V, and VI) are expected to be the major areas of cadmium waste generation. The Great Lakes Region (Federal Region V) accounts for 38 percent of gross generation between 1975 and 2000, by far the largest regional share. Gross generation in the South Central Region shows the highest growth rates during the period--6.7 and 5 percent annually in the High and Low Growth Scenarios. In contrast, the New York-New Jersey Region and the Southeast Region would account for the greatest portions of net cadmium discharges.

However, projections reported in this section are based upon assumptions of continued widespread cadmium use in the electroplating industry and do not account for recent initiatives to control this compound through the application of substitute coatings. An agreement between EPA and the Department of Defense (DOD), the largest user of electroplated products, has recently been reached to investigate alternative coatings. It is anticipated that DOD's requirements and specifications will have a domino effect on the industry because

TABLE 6-14
TRENDS IN DISCHARGES OF TOXIC POLLUTANTS
HIGH GROWTH SCENARIO
1975 AND 2000

	1975		2000			
Pollutant	Gross Discharges*	Net Discharges*	Gross Discharges*	Percent Change	Net Discharges*	Percent Change
Cadmium	400	70	990	+147	20	-72
Chromium	31,550	8,330	83,030	+163	3,050	-63
Copper	48,500	36,150	85,900	+77	80,500	+122
Cyanide	30,100	5,100	80,300	+167	3,900	-24
Mercury	360	2	130	-64	0	---
Phenol (as oil and grease)	73,300	14,100	973,500	+1228	1,750	-82
Phenol (as dissolved solids)	17,300	5,300	14,600	-16	4,400	-17

*Tons

of its dependence upon defense contract work. Thus, if substitute coatings are found, projections of cadmium generated by electroplaters could be significantly overstated.

Chromium. The steel and electroplating industries are the major sources of chromium wastes. Chromium in the untreated wastewaters of the steel industry is projected to increase at an annual rate of 3.5 percent in the High Growth Scenario and 2.9 percent in the Low Growth Scenario. Gross generation of chromium in the electroplating industry is projected to increase at even higher rates--3.8 percent and 3.1 percent annually in the two scenarios. Total chromium wastes consequently would increase between 1975 and 2000 from about 30 thousand tons to over 80 thousand tons in the High Growth and over 65 thousand tons in the Low Growth Scenario.

However, this increase in chromium wastes brought on by economic growth would be more than offset by compliance with effluent limitations guidelines (Table 6-15). Net discharges of chromium by the steel industry alone are projected to decline by 2000 to only 2 percent of the estimate for 1975. The electroplating industry would eliminate all chromium from its final effluent by 2000.

Conversion of coal to synthetic fuels would become an important source of chromium wastes by 2000. In the High Growth Scenario, gross generation of chromium during coal conversion is projected to approach 11 thousand tons, about 15 percent of the national total. Most coal conversion is expected in the Southeast, Great Lakes, and Mountain Regions (Federal Regions IV, V, and VIII); by 2000 it would account for the largest part of chromium generation in Federal Region VIII. Only under the assumption of high economic growth would chromium generation by coal conversion facilities pose a possible problem, since the industry would see almost no development in the Low Growth Scenario.

Trends in the control of chromium in most Federal Regions are expected to follow the downward national trend. However, net discharges in the Middle Atlantic, Southeast, Great Lakes, and Northwest Regions (Federal Regions III, IV, V, and X) deviate slightly. Federal Regions III, V, and X are expected to experience greater than average declines in net discharges from point sources between 1975 and 2000. In 1975, net discharges of chromium in these regions were mostly attributable to the steel industry. The large reduction in discharges of chromium projected for this industry accounts for these greater than average regional declines.

Federal Region IV's net discharges would decrease over the 1975 to 2000 time period, but much more slowly than the national rate. Furthermore, this region is projected to experience the greatest

TABLE 6-15
CHROMIUM DISCHARGES FOR SELECTED INDUSTRIAL GROUPS
1975 and 2000
(TONS)

	1975		2000			
			High Growth		Low Growth	
Industry	Gross	Net	Gross	Net	Gross	Net
Steel	20,160	4,330	49,300	130	41,400	100
Electroplating	4,700	970	11,800	0	9,980	0
Inorganic Chemicals	1,300	200	3,450	3	2,740	2
Electric Utilities: Oil/Coal	1,080	1,080	870	20	960	20
Electric Utilities: Nuclear	50	50	400	400	320	320
Textiles	600	600	1,580	1,580	1,100	1,100
Other	3,600	1,140	17,630	920	9,850	420
Total[a]	31,550	8,370	83,030	3,050	66,350	1,960

[a] Rounding may create inconsistencies in addition.

levels of net chromium discharges. The textile and organic chemicals industries are expected to be the major sources of these discharges.

Copper. Gross generation of copper in wastewaters is expected to increase substantially between 1975 and 2000 (Table 6-16). From 50 thousand tons in 1975, gross copper loadings to untreated wastewaters would increase by three-fourths in the High Growth Scenario and two-thirds in the Low Growth Scenario. Coal-fired electric utilities are expected to be the predominant generator of copper. Between 1975 and 2000, the gross generation of copper wastes by coal-fired utilities would increase from about half of all point source generation to more than three-fourths of all copper loadings to untreated waste streams.

In contrast, net copper discharges are expected to drop sharply. From an estimate of 36 thousand tons for 1975, net copper discharges are projected to decline to just 100 tons by 2000 in the High Growth Scenario (less than 1 percent of the 1975 volume). This decline would occur only with full compliance with BAT standards.

The Middle Atlantic, Southeast, and Great Lakes Regions (Federal Regions III, IV, and V) are expected to have the most gross copper waste, with increases from 7 to 11 thousand tons, 10 to 20 thousand tons, and 12 to 19 thousand tons, respectively, from 1975 to 2000 in the High Growth Scenario. These increases would occur primarily because of the reliance on coal-fired power plants by those regions.

Other major sources of copper include the electroplating industry and oil- and gas-fired electric utilities. Gross copper wastes from the electroplating industry would nearly triple, rising from 5 thousand tons in 1975 to 13 thousand tons in 2000 in the High Growth Scenario. In contrast, gross copper wastes from oil- and gas-fired utilities are expected to decline drastically, primarily because coal and nuclear units will supplant many oil- and gas-fired units during the 1975 to 2000 period. Copper generated by oil-fired utilities would drop to about half of the 1975 level, while copper from gas-fired utilities would drop to only 6 percent of the 1975 value (High Growth Scenario).

With full compliance with BAT standards, 99 percent of the copper would be removed from wastewaters by 1985. In particular, net discharges from electric utilities and from the electroplating industry would be eliminated. That would shift the main responsibility for copper discharges to the organic chemicals and aluminum industries. Net discharges from the organic chemicals industry are expected to decline from 80 to 70 tons between 1975 and 2000. However, because other industries would eliminate net discharges of copper, the organic chemicals industry would emerge as the source of over two-thirds of all point source discharges of copper in 2000 (High Growth Scenario). The aluminum industry is projected to increase its

TABLE 6-16
COPPER DISCHARGES FOR SELECTED INDUSTRIAL GROUPS
1975 and 2000
(TONS)

Industry	1975		2000			
			High Growth		Low Growth	
	Gross	Net	Gross	Net	Gross	Net
Electroplating	5,200	880	13,200	0	11,100	0
Electric Utilities: Old Coal	25,350	20,740	20,300	0	22,500	0
Electric Utilities: New Coal	------	------	46,050	0	34,050	0
Electric Utilities: Oil	8,600	7,030	4,500	0	6,600	0
Electric Utilities: Natural Gas	9,000	7,330	520	0	5,200	0
Electric Utilities: Nuclear	70	60	530	0	430	0
Other	400	110	870	100[a]	700	100[a]
Total[b]	48,500	36,150	85,900	100	80,500	100

[a] Primarily organic chemicals and aluminum.

[b] Rounding may create inconsistencies in addition.

net discharges of copper from 13 tons in 1975 to almost 30 tons in 2000 in the High Growth Scenario.

The geographic distribution of net copper discharges in 1975 was similar to gross generation; the Middle Atlantic, Southeast, and Great Lakes Regions (Federal Regions III, IV, and V) discharged the most copper. The waters of Federal Region V received 8.4 thousand tons of copper; the waters of Federal Region IV, 8.1 thousand tons; and the waters of Federal Region III, 5.5 thousand tons. Approximately 60 percent of all the discharged copper came from coal-fired electric utilities.

By 2000, the regional distribution would change, due to a drastic reduction in net discharges by the electric utilities. The Southeast and South Central Regions (Federal Regions IV and VI) are then expected to receive almost half of the nation's total net discharges of copper. Federal Region VI, which produces one quarter of the nation's total aluminum, is projected in the High Growth Scenario to discharge almost 30 tons (25 tons from the aluminum industry) by 2000. By 2000, Federal Region IV is expected to discharge 19 tons, of which 17 tons would come from the organic chemicals industry.

Cyanide. Gross generation of cyanide wastes is expected to increase substantially between 1975 and 2000, while net discharges would decline. From estimated 1975 discharges of 30 thousand tons, gross discharges are projected in the High Growth Scenario to increase to 80 thousand tons by 2000. In the Low Growth Scenario, discharges are expected to increase to 60 thousand tons. The electroplating industry is and would remain the major generator of cyanide.

Because cyanide is extremely toxic, discharges were strictly controlled in 1975--only one-sixth of the total was discharged in final effluents. (Abatement efficiency is projected to improve during the 1975 to 2000 period.) Net discharges of cyanide are projected in the High Growth Scenario to decline from 5 thousand tons in 1975 to less than 4 thousand tons in 2000. This decline derives from the anticipated elimination of net cyanide discharges by the electroplating industry and a 95 percent reduction in net discharges by the steel industry.

Mercury. The discharge of mercury to untreated wastewaters is expected to decline from over 350 tons in 1975 to about 130 tons by 2000 in the High Growth Scenario and to about 100 tons in the Low Growth Scenario. However, total net discharges by 2000 are estimated to be less than 5 tons in both scenarios. Over 99 percent of mercury discharges came from the inorganic chemicals industry in 1975; projections indicate that by 2000 that industry would discharge less than 1 ton of mercury to the environment annually.

The Southeast and South Central Regions (Federal Regions IV and VI) are expected to be the major generators of gross mercury wastes. Gross generation in Federal Region VI is expected to decrease from over 100 tons in 1975 to under 50 tons in 2000 in the High Growth Scenario and to about 40 tons in the Low Growth Scenario. Federal Regions II and III are also responsible to some extent for gross mercury generation. For each of these regions, as for the nation as a whole, net discharges by 2000 would be insignificant.

Phenol. Phenol and phenolic compounds are present in industrial wastewaters both as dissolved solids and as oil and grease. In 1975, point sources generated 17 thousand tons of phenol as dissolved solids and 73 thousand tons as oil and grease. Economic growth in both scenarios and the emergence of new energy technologies are expected to increase generation of phenol to untreated wastewaters substantially over the 1975 to 2000 period. From the 90 thousand ton total in 1975, SEAS projections indicate that by 2000, nearly 1 million tons of phenolic waste would be generated in the High Growth Scenario and almost 600 thousand tons in the Low Growth Scenario. This growth rate is wholly attributable to phenols as oil and grease, as the amount of phenolic substances generated as dissolved solids is actually expected to decline between 1975 and 2000.

Economic growth in the textiles, organic chemicals, plastics, petroleum refining, and steel industries is responsible for much of the projected increase in phenols as oil and grease. More important by far, however, is the introduction of certain energy technologies during the 1975 to 2000 period. High- and low-Btu gasification of coal and combined-cycle coal-fired electric generation are expected to produce large quantities of phenol.

In both scenarios, coal gasification and combined-cycle electric generation account for nearly 80 percent of all waste phenols produced by point sources. However, full compliance with BAT standards would prevent the release of most phenolic compounds into the environment. This is particularly evident with respect to the coal gasification and combined-cycle electric utility point sources. Virtually all phenols in wastewaters would be abated by these industries. For example, of the 660 thousand tons of phenol expected to be generated annually by 2000 during coal gasification, only 90 tons are expected to be discharged to the environment (High Growth Scenario). Abatement practices in the coal-fired combined-cycle electric utilities are expected to be such that no phenolic compounds would be discharged.

Only the textiles industry is expected to discharge more phenols as oil and grease in 2000 than in 1975. Net discharges of phenols from this source are projected to increase from 560 tons in 1975 to 1,500 tons annually by 2000 in the High Growth Scenario. However, total net discharges of phenols as oil and grease from all identified point sources during that period are expected to decline by approximately 90 percent. Gross generation and net discharges of phenol as oil and grease projected by industrial point sources for 1975 and 2000 are shown in Table 6-17.

Net discharges of phenolic substances as dissolved solids are also expected to decline (Table 6-18). However, this decline would be due less to compliance with effluent limitations guidelines than to process changes in the steel industry. The generation of phenols as dissolved solids waste in the steel industry is expected to decline from 15 thousand tons in 1975 to under 10 thousand tons annually by 2000 in the High Growth Scenario (an even greater decline is expected in the Low Growth Scenario). This decline is attributable to an expected shift away from beehive coking operations in the industry.

Only the steel and glass industries are expected to discharge smaller quantities of phenols (as dissolved solids) to the environment in 2000 than in 1975. The textiles, organic chemicals, and aluminum industries all would discharge more phenols. As a result, in 2000 net discharges of phenols as dissolved solids are projected to be 2.5 times greater than net discharges of phenols as oil and grease, despite the fact that point sources would generate 65 times more phenol as oil and grease than as dissolved solids.

Regional trends in phenol discharges vary considerably. Regions where the generation of phenols is expected to increase significantly are those expected to host coal gasification facilities and coal-fired combined-cycle power plants. In particular, the Southeast, South Central, Central, and Mountain Regions (Federal Regions IV, VI, VII, and VIII) are projected to experience considerable growth in these emerging technologies. As a consequence, phenols in untreated wastestreams in Federal Region VIII are projected in the High Growth Scenario to increase from 2 thousand tons to nearly 350 thousand tons annually by 2000. Increases in the generation of phenols in Federal Regions IV, VI, and VII, although less, are nonetheless significant. Full compliance with effluent limitations guidelines by new technologies should, however, reduce net discharges of phenol.

The Middle Atlantic, Great Lakes, and South Central Regions (Federal Regions III, V, and VI) are projected to experience significant declines in net discharges of phenols. In Federal Regions III and V, net discharges are projected in the High Growth Scenario to decline from over 3 thousand tons in 1975 to less than 500 tons by 2000. This is attributable primarily to assumed compliance with effluent limitations guidelines by the steel industry, which would mean removal of virtually all phenols from wastewaters. In Federal Region VI, net discharges of phenol are projected to decline from

TABLE 6-17
PHENOL (AS OIL AND GREASE) DISCHARGES FOR SELECTED INDUSTRIAL GROUPS
1975 and 2000
(TONS)

	1975		2000			
			High Growth		Low Growth	
Industrial Group	Gross	Net	Gross	Net	Gross	Net
Textiles	560	560	1,500	1,500	1,000	1,000
Organic Chemicals	28,800	11,100	84,700	160	68,900	130
Plastics	1,400	200	4,500	10	4,000	10
Petroleum Refining and Storage	41,400	1,300	59,900	0	50,000	0
Steel	1,100	960	1,900	10	1,700	10
Coal--Synthetic Fuels	0	0	663,000	90	437,000	60
Electric Utilities:						
Coal	0	0	117,000	0	19,500	0
Total[a]	73,300	14,100	973,500	1,750	582,100	1,210

TABLE 6-18
PHENOL (AS DISSOLVED SOLIDS) DISCHARGES FOR SELECTED INDUSTRIAL GROUPS
1975 and 2000
(TONS)

	1975		2000			
			High Growth		Low Growth	
Industrial Group	Gross	Net	Gross	Net	Gross	Net
Textiles	50	50	120	120	160	160
Organic Chemicals	1,500	1,500	3,600	3,600	2,600	2,600
Glass	460	70	920	0	870	0
Steel	15,000	3,300	9,300	30	8,300	30
Aluminum	270	270	630	630	600	600
Other	3	3	10	10	10	10
Total[a]	17,300	5,300	14,600	4,400	12,400	3,300

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[a] Rounding may create inconsistencies in addition.

over 7 thousand tons in 1975 to 350 tons by 2000, despite considerable growth in coal gasification output.

The Southeast Region (Federal Region IV) is host to a large proportion of the organic chemicals industry at present and projections indicate an increase in the region's share over time. This is reflected in the considerable projected growth in the generation of phenols by the industry. Gross loadings of phenol, both as dissolved solids and as oil and grease, are projected to increase from 16 thousand tons in 1975 to 53 thousand tons annually by 2000 in the High Growth Scenario.

However, nearly all phenolic compounds generated by the industry are expected to be in the form of dissolved solids. Compliance with BAT standards would reduce the quantity of phenols in this form considerably. (On the other hand, no removal of phenols as oil and grease is anticipated in current projections.)

Discharges of phenols by the aluminum industry are expected to be a primary factor in Southeast Region trends. Regional net discharges are projected to decline by one-fourth over the 1975 to 2000 period in the region, despite considerable improvements expected in wastewaters discharged by the steel, organic chemicals, plastics, and petroleum refining industries, since net discharges by the aluminum industry are projected in the High Growth Scenario to increase from 60 tons in 1975 to over 160 tons annually by 2000. In addition, only marginal improvement is expected in the treatment of phenols by the textiles industry, so net discharges in Federal Region IV would decline only from 1.5 thousand tons in 1975 to 1.1 thousand tons by 2000.

Other Pollutants

Several other kinds of pollutants can seriously degrade water quality and decrease its value for various uses, including recreation. This section examines four such pollutants: chemical oxygen demand (COD), fecal coliform bacteria, pH, and thermal pollution. Projections of gross COD loadings are made by SEAS, but the latter three pollutants are not addressed in the model and data and projections from other sources are used to examine them.

SEAS projections do not estimate net discharges from some industrial point sources; this shortcoming is taken into account, to the extent possible, in the following analysis of national and regional trends.

Chemical Oxygen Demand. Chemical oxygen demand measures the total quantity of oxygen required to oxidize wastes and natural oxygen demanding substances to carbon dioxide and water under severe chemical and physical conditions. Because more compounds can be chemically oxidized than can be biologically oxidized, the COD of a waste is generally higher than its BOD and thus the indicator is invariably a more inclusive measure of oxygen demand than is BOD.

Compounds which are more resistant to biological oxidation are attracting greater concern not only because of their slow but continuing oxygen demand on the receiving water, but also because of their potential effects on human health and aquatic life. Many of these substances have been found to have carcinogenic, mutagenic, and other adverse effects. Concern about these substances has increased as a result of demonstrations that they can contaminate downstream water intakes. The commonly used disinfectants do not remove them from drinking water, and chlorination may actually convert them into even more hazardous materials.

Gross generation of COD is expected to increase substantially between 1975 and 2000, as shown in Table 6-19. From estimated 1975 generation of 20 million tons, annual gross COD loadings are projected in the High Growth Scenario to increase to 34 million tons by 2000. In the Low Growth Scenario, the increase in gross generation is expected to be less, but still significant--30 million tons annually by 2000.

In contrast to gross generation, net discharges[42] of COD are projected to decline slightly between 1975 and 2000 in both scenarios. From a 1975 estimate of 7.6 million tons, annual net COD discharges are expected to decline to 7.1 million tons in the High Growth Scenario. The expected decline is greater in the Low Growth Scenario, with discharges expected to be 6.6 million tons by 2000. The relative improvement in net discharge trends compared to gross generation occurs because net discharges are projected to decline between 1975 and 1985 as a result of the full compliance with effluent limitations guidelines assumed for industrial point sources by 1985.

There are six major industrial sources of COD--organic chemicals, meat products processing, petroleum refining and storage, textiles, plastics, and electric utilities. Together they generated

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[42] Projections of net discharges of COD, as calculated by SEAS, cannot be used because of incomplete information in the SEAS data base. To project net COD discharges, the removal of BOD from each industry was applied to COD discharges from those same industries. The percentage similarity between BOD and COD is the justification for using this procedure.

TABLE 6-19
COD DISCHARGES FOR SELECTED INDUSTRIAL GROUPS
1975 and 2000
(THOUSANDS OF TONS)

	1975		2000			
			High Growth		Low Growth	
Industrial Group	Gross	Net	Gross	Net	Gross	Net
Municipal Wastewater Treatment Facilities	15,000	6,040	21,000	5,160	19,800	4,840
Organic Chemicals	990	250	2,700	370	2,100	290
Meat Processing	670	100	1,060	130	910	170
Petroleum Refining and Storage	300	60	400	20	350	20
Textiles	490	110	1,100	30	770	20
Plastics	290	80	1,200	60	940	50
Electric Utilities	750	750	1,200	1,200	1,200	1,200
Other	1,150	250	5,340	80	3,850	6,560
Total[a]	19,640	7,600	34,000	7,060	29,900	6,560

[a] Rounding may create inconsistencies in addition.

three-fourths of the industrial COD in 1975 and discharged 90 percent.

The organic chemicals industry is expected to be the most significant industrial source between 1975 and 2000. In 1975, that industry generated almost 1 million tons of COD, 20 percent of all COD generated by industry. This relative contribution is expected to remain about the same, so that by 2000, gross generation of COD by the organic chemicals industry would increase to 2.7 million tons annually.

The predominant contributor to trends in net COD discharges is municipal wastewater treatment facilities. These treatment plants were responsible for 6 out of 8 million tons of net point source discharges of COD in 1975. Although compliance with BAT standards is expected to be successful in removing a greater percentage of COD generated by 1985, municipal plants are still expected to discharge 5 million tons in 2000. Throughout the entire 1975 to 2000 time period, treatment plants are expected to be responsible for 70 to 75 percent of all point source discharges of COD.

The prominence of municipal treatment plants in COD generation estimates results in distinctive regional impacts. For the most part, regions which have the greatest increases in population will also have the greatest increases in COD. The South Central Region (Federal Region VI) is expected to have the greatest increase in generation of COD between 1975 and 2000--an increase of 72 percent. Not only is the region expected to have a 34 percent increase in population, but its COD waste from industrial sources are expected to triple. The Southeast Region (Federal Region IV) is expected to have the greatest increase in population, which is the principal reason for the expected 54 percent increase in gross generation of COD between 1975 and 2000.

Federal Region IV is the only region expected to have an increase in net discharges of COD. In 1975 net discharges were estimated to be 800 thousand tons, while by 2000 they are expected to increase to 900 thousand tons. Not only is the population increase of 37 percent responsible for this projected increase, but also a greater percentage of the population is expected to be on centralized treatment, further increasing the discharges of COD.

Fecal Coliform Bacteria. Bacterial densities are a standard measure of the potential for public health problems or disease problems for aquatic life.[43] Pathogenic bacteria--those which threaten human health--make up only a small proportion of all bacteria in water. But since pathogens are difficult to detect directly, counts of all fecal coliform bacteria are used as an indicator of the presence of pathogens in water bodies. These counts are expressed in terms of the mean number of fecal coliform colonies per 100 milliliters. This measure assumes that polluted waterways are likely to contain pathogens in proportion to the concentration of fecal coliform bacteria. The validity of this surrogate is often questioned,[44] but the number of fecal coliforms is at least indicative of the degree of health risk associated with using certain water sources for drinking, swimming, or shellfish harvesting.[45]

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[43] U.S. Environmental Protection Agency, Office of Water & Hazardous Materials, Quality Criteria for Water, Washington, DC, July 1976, p. 44.

Recommended water quality standards for swimming suggest a maximum log mean fecal coliform bacteria count of 200 colonies per 100 milliliters. Although EPA previously used this standard as part of their definition of secondary treatment of wastewater, it has been eliminated. As a result, it can no longer be assumed that municipal treatment plants will discharge only 200 fecal coliform per 100 milliliters of treated wastewaters.

Other water quality standards apply to shellfish harvesting waters, which should not exceed 14 colonies per 100 milliliters.[46] Raw waters used as sources for public water supplies ought not to contain more than 2,000 fecal coliform colonies per 100 milliliters. The standard for drinking water after treatment is as low as 1 colony per 100 milliliters.[47] However, actual legal standards for fecal coliform bacteria concentrations in streams are determined by the states. Although most state standards are generally similar to those above, large differences exist in some instances.

Coliform bacteria are discharged from both point and non-point sources. In urban areas, major sources include inadequately disinfected municipal wastewater, urban stormwater runoff, and combined sewer overflow. In rural areas, feedlots, stock grazing areas, and malfunctioning septic systems are important sources. As a result, fecal coliform bacterial concentrations tend to be high in water bodies near urban areas, in livestock-raising areas, and in areas where streams have flow rates too low to dilute feedlot runoff.[48]

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[44] National Commission on Water Quality, Staff Draft Report, Washington, D.C., July 1976, p. 44.

[45] U.S. Environmental Protection Agency, Office of Water & Hazardous Materials, Quality Criteria for Water, Washington, D.C., July 1976, p. 44.

[46] Ibid, p. 42.

[47] U.S. Geological Survey, Quality of Rivers of the United States, 1974 Water Year--Based on the National Stream Quality Accounting Network, (NASQAN), Open-File Report 77-151, Reston, Virginia, February 1977, p. 33.

Trends in average violation rates[49] in water around 25 major cities in the United States indicate that coliform bacteria counts improved slightly over the 1968 to 1976 period.[50] Violation rates downstream from 18 cities declined, but they increased in 4 cities and remained unchanged in 2 others. Overall, an average 10 percent decline in violation rates was noted, which can be attributed to improved treatment of sewage by municipalities.[51] Bacteria levels upstream from these urban areas have also tended to decline, although not as markedly as downstream levels.

Despite this improvement, fecal coliform bacterial counts exceeded the recommended maximum for safe swimming in almost 60 percent of all samples. Geographical variations exist in violation rates; while the standard was exceeded only 25 percent of the time in two cities sampled, several cities exceeded the standard in over 75 percent of all samples taken.

No consistent projections of fecal coliform bacterial contamination are known to exist at the national level. However, the National Commission on Water Quality has attempted to assess the impacts of effluent limitations guidelines for municipal treatment facilities on water quality at 41 sites in the United States from which trends can be inferred.[52] In 1975, 70 percent of the 41 sites were found to continuously violate coliform bacterial criteria levels. Assumed conformance by municipal treatment plants to 1977 secondary treatment standards could reduce this proportion of sites to 15 percent (Figure 6-12). Control of combined sewer overflows, if achieved by 1983, would reduce the number of sites with continuous excessive fecal coliform bacterial counts to 5 percent of sites.

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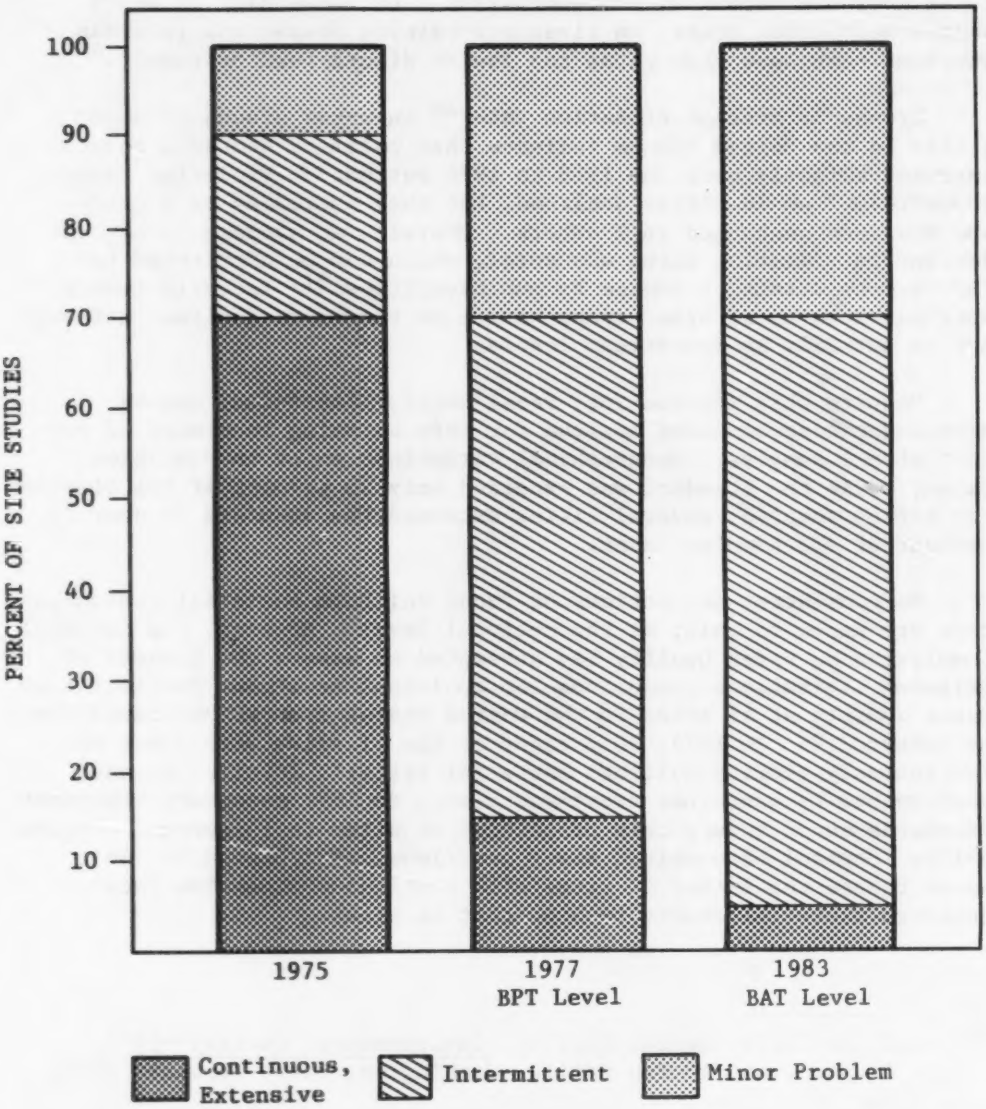
[48] Council on Environmental Quality, Environmental Quality--1977, U.S. Government Printing Office, Washington, D.C., December 1977, p. 203.

[49] A violation rate is the percent of water samples that exceed 200 colonies per 100 milliliters.

[50] Council on Environmental Quality, Environmental Quality--1977, U.S. Government Printing Office, Washington, D.C., December 1977, p. 211.

[51] National Commission on Water Quality, Staff Draft Report, Washington, D.C., November 1975, p. IV-40.

[52] Ibid.



Source: National Commission on Water Quality, Staff Draft Report, Washington, D.C., November 1975, p. IV-40.

FIGURE 6-12
ESTIMATES OF COLIFORM BACTERIA POLLUTION AT 41 SITES UNDER 1975 CONDITIONS, AFTER BPT, AND AFTER BAT

Periodic fecal coliform bacterial contamination would still be expected in most areas studied because of discharges from non-point sources. As greater control of bacterial discharges from municipal treatment plants and combined sewer overflow is achieved, agricultural and urban runoff are projected to become more evident as sources of coliform bacterial pollution. This shift from point to non-point sources is likely to produce greater benefits than those attributable simply to lower bacterial concentrations. Since coliforms and most pathogenic bacteria die off fairly rapidly in the natural environment, their discharge to waterways on a more intermittent basis, which characterizes non-point pollution, is anticipated to detract less from ambient water quality than continuous point source discharges.

Since the National Commission on Water Quality report predated the Clean Water Act of 1977 with its revised compliance schedule, and did not incorporate reported delays in the Construction Grants Program, its projections of water quality in sampled regions are probably optimistic. Data for 1977[53] indicate that widespread bacterial pollution problems still exist, with little change in water quality observed over the 1975 to 1977 period. Fewer than 10 percent of all National Stream Quality Accounting Network (NASQAN) stations showed a decline in fecal coliform bacterial counts over that period. However, compliance with effluent limitations guidelines by municipalities could eventually reduce bacterial pollution from point sources, even though control of bacteria from non-point sources will still be a problem.

pH. The pH of a water sample is a measure of the concentration of hydrogen ions in it, and indicates acidity or alkalinity of the composite solution. The range of pH is from 0 to 14; a pH value of 1 is very acidic (e.g., battery acid), pH 7 is neutral (e.g., distilled water) and pH 13 is very alkaline (e.g., lye). The lower the pH value, the more hydrogen ions in the solution and the stronger the acid. Because pH is expressed on a logarithmic scale, a change in one pH unit reflects a 10-fold change in acidity or alkalinty.

Usually, water is considered habitable to marine species if its pH value lies within the range of 6.5 to 9.0. Outside this range, fish suffer adverse physiological effects which become more severe as the deviation from these values increases. It has been shown that at pH levels below 5.6, the reproductive capability of adult fish and the survival ability of eggs and young fish decline and eventually fail. Below pH 5 the survival of even large fish becomes precarious. Since all aquatic organisms are affected, surviving fish must also contend with reduced food variety.[54] In addition to its direct effects, pH influences the toxicities of many compounds in water. For example, aluminum and cyanide toxicity to fish increased as the pH is lowered, while increasing pH levels promote higher concentrations of ammonia in water, which is also toxic to marine life.[55]

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[53] U.S. Environmental Protection Agency, Office of Water Planning and Standards, National Water Quality Inventory: 1977 Report to Congress, U.S. Government Printing Office, Washington, D.C., October 1978, p. 2. Also, Council on Environmental Quality, Environmental Quality--1978, U.S. Government Printing Office, Washington, D.C., December 1978, p. 46.

The incidence of low pH in the water is primarily a problem in the eastern part of the United States. Studies have shown a dramatic decline in the pH of waterways in the northeastern United States and Canada between the 1950s and the mid-1970s. Over 100 lakes in the Adirondack Mountains of New York are now devoid of fish because of increased acidity.[56]

The evident cause of declining pH in water is acid precipitation, which occurs when oxides of sulfur and nitrogen are emitted into the atmosphere and then fall back to earth as solutions in rain. These acids are generated primarily from vast quantities of combustion gases from the burning of fossil fuels. As the nation is expected to burn more coal, the problem of high acidity in the water is expected to increase. As a result, problems associated with low pH counts are expected to become of greater concern throughout the country. (See Chapters 4 and 5 for further discussions of acid precipitation.)

Maintaining a suitable level of pH in the raw water used for public water supplies helps control the corrosion of plant equipment and water pipes. Such corrosion can be expensive, and can release toxic metal ions such as copper, lead, zinc, and cadmium to the drinking water supply.

Thermal Pollution. Temperature changes in receiving waters caused by industrial discharges can have profound effects upon water quality. These effects range from discomfort for swimmers in water outside the 20°C to 30°C range to a restructuring of aquatic ecosystems.[57] Demands upon the dissolved oxygen in water are increased by higher temperatures, which accelerate the decomposition of organic matter. This process is exacerbated by the lower solubility of oxygen in warm water. In addition, available data indicate that toxicity of some pollutants increases at higher temperatures.[58]

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[54] Glass, N.R., "Mounting Acid Rain," EPA Journal, July/August 1979.

[55] U.S. Environmental Protection Agency, Office of Water and Hazardous Materials, Quality Criteria for Water, U.S. Government Printing Office, Washington, D.C., July 1976, p. 178.

[56] Ibid.

Projections of thermal pollution discharges are not attempted in SEAS. However, in this section we identify the main sources of thermal pollution and discuss mandated restrictions on industrial dischargers.

Thermal discharges primarily result from the use of water for cooling (Table 6-20). Steam electric power plants are major sources, accounting for 90 percent of the water used for cooling purposes. Other major sources include the steel products and inorganic chemicals industries.

Control of thermal discharges was mandated in the Federal Water Pollution Control Act Amendments of 1972.[59] According to proposed EPA guidelines for steam electric power plants, generating units of 500 MW and over placed in service before January 1, 1970 would have no restriction on cooling water discharges; those placed in service after that date were to have no discharges. Plants of 25 to 499 MW capacity would not be limited if the facility was in service before January 1, 1974; no discharges were permitted from plants in that capacity range after that date. No discharge restrictions were placed on units less than 25 MW.[60] Although the courts have remanded these federal guidelines,[61] many states have adopted similar guidelines to control thermal discharges.

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[57] DeSylva, D.P., "Theoretical Considerations of the Effects of Heated Effluents on Marine Fishes," in P.A. Krenkel and F.C. Parker, eds., Biological Aspects of Thermal Pollution, Vanderbilt University Press, Nashville, Tennessee, 1969.

[58] Coutant, C.C., "Biological Aspects of Thermal Pollution II Scientific Bases for Quality Criteria Standards at Power Plants," CRC Critical Review in Environment Contamination, Vol. 3, 1972.

[59] Federal Water Pollution Control Act Amendments of 1972, PL 92-500.

[60] U.S. Environmental Protection Agency, Development Documents for Effluent Limitations Guidelines and New Source Performance Standards for the Steam Electric Power Generating Point Source Category, EPA 440/1-74029-a, U.S. Government Printing Office, Washington, D.C., October 1974, p. 5.

[61] FERC 1033, Appalachian Power v. Train, 4th Circuit Court, 1976.

TABLE 6-20
COOLING WATER USED BY SELECTED INDUSTRIES
(BILLIONS OF GALLONS USED IN 1968[a])

Industrial Group	Use for Cooling: Air Conditioning	Use for Cooling: Steam Electric Power	Use for Cooling: Other Cooling	Total Use, Process Waters	Use for Cooling as Percent of Total
Pulp & Paper	16	389	204	1,916	24
Inorganic Chemicals	30	613	2,075	3,368	65
Plastics & Synthetics	56	61	372	635	59
Petroleum Refining & Storage	3	167	1,056	1,427	74
Steel Products	25	1,147	2,046	4,392	47
Steam Electric Power	—	40,000	--	40,000	99

[a] Water use as measured by intake (reuse or recirculation not included).

Source: National Commission on Water Quality, Staff Draft Report, Washington, D.C., November 1975, p. IV-22.

Water quality impacts from thermal discharges relate closely to the characteristics of receiving waters. Estuaries, with complex patterns of fresh and saline water and large populations of marine organisms, are very sensitive to cooling system discharges. In contrast, freshwater impoundments appear to be either insensitive to thermal impacts or able to adapt to them, although changes in the local ecosystem can result in the process of adaptation.[62]

Little information is available for forecasting thermal discharges. The National Commission on Water Quality attempted to predict the number of existing and planned steam electric power plants that, by 1983, would be required to use alternatives to "once-through" cooling systems, taking into account exemptions permitted in the 1972 Act.[63] Their estimates and some EPA estimates given in the same report, on the need for alternative cooling systems are shown in Table 6-21. However, because site-specific data were not considered, these estimates are highly uncertain.

Further uncertainty still exists as to whether state limitations guidelines for thermal discharges can be enforced in light of thermal exemptions permitted by the FWPCA Amendments of 1972. More research is necessary before reliable estimates of thermal discharges and their associated impacts can be projected into the future.

6.3 NON-POINT SOURCE POLLUTANTS

HIGHLIGHTS OF SECTION 6.3

- Water pollution from non-point sources is estimated to affect about 90 percent of the drainage basins in the United States. Pollution discharges from non-point sources greatly exceed the discharges from point sources. Non-point loadings are generally accompanied by high dilution; therefore their impact on water quality is uncertain. Uncontrolled non-point source pollution may contribute to prevent achieving national water quality goals.

- Agricultural activities have the most widespread pollution impact of all non-point sources, followed by urban runoff. Combined sewer overflows cause some problems, primarily in the eastern United States. Discharges from these sources (in the absence of controls) are projected to increase from 1975 to 2000 in almost all Federal Regions.

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[62] National Commission on Water Quality, Staff Draft Report, Washington, D.C., November 1975, p. IV-44.

[63] Ibid.

TABLE 6-21
COMPARISON OF ESTIMATES OF NEEDS FOR ALTERNATIVE POWER PLANT COOLING SYSTEMS[a]

Type of Water Source Receiving Thermal Loadings	Percent of Power Plants Needing Alternative Cooling Systems	
	Estimate by National Commission on Water Quality	Estimate by EPA
Oceans	20	0
Estuaries	62	50
Rivers	20	26
Rivers/Impoundments	100	NA
Impoundments	0	NA
Lakes	10	50
Man-Made Lakes	0	NA

[a] Plants at which continuation of "once-through" cooling will damage indigenous population.

Source: National Commission on Water Quality, Staff Draft Report, Washington, D.C., November 1975, p. IV-43.

- Mining and construction activities can have substantial localized water pollution impacts; increase in these activities from 1975 to 2000 may cause intermittent problems. Silviculture has caused localized pollution but is not expected to have significant long-term effects.

- In volume, the major non-point source pollutant is sediment, and cropland is responsible for almost half of that total. However, other pollutants--BOD, nutrients, toxics, pesticides, and acids--can also be significant because even small quantities can affect ecological systems.

- Little progress has been made in controlling non-point source pollution. However, if use of Best Management Practices that promote proper land use becomes widespread, non-point source discharges by 2000 might be reduced below 1975 levels.

6.3.1 Introduction

Problem Definition and Regulatory Background

Non-point sources of pollution generally involve the contamination of receiving waters by stormwater runoff. These diffuse sources discharge pollutants to the nation's waters on an intermittent basis, because stormwater runoff and the pollutant source (e.g., construction, timber harvesting) are not continuous processes. Thus, the impacts on water quality from non-point sources are storm event related.

Although non-point source water pollution may be less concentrated and conspicuous than pollution from industrial and municipal point sources, non-point source pollution is estimated to be greater in overall magnitude than point source discharges:

- Sediment loads from man-made non-point sources are estimated to be 360 times higher than those from municipal and industrial point sources after treatment, and three times higher than those from natural background.

- Biochemical oxygen demand from non-point sources is estimated to be five times higher than either treated point sources or natural background.

- Total nitrogen from non-point sources is estimated to be four times higher than that from treated point sources and three times higher than natural background. Total phosphorus from non-point sources is slightly higher than from point sources and twice as high as natural background.

- Loadings of fecal coliform bacteria from non-point sources will be at least 50 times higher than from point sources, once secondary treatment with disinfection is achieved for all municipal sources.[64]

Moreover, since non-point source discharges of pollutants can generally occur anywhere along a water body, they ordinarily cannot be handled by collection and treatment.

Non-point sources of pollutants include agriculture, some mining, urban and rural construction, sewered and unsewered urban stormwater runoff, silviculture, and hydrologic modifications (i.e., dredging, excavating, or dam installation), and those releases arising from land not disturbed by man's activities (i.e., natural background sources).[65] Although EPA promotes the use of Best Management Practices (BMP's) to reduce water pollution from some of these sources, non-point sources are especially difficult to control, and are not subject to EPA effluent guidelines. Moreover, even with the control of man originated non-point source pollution, pollution releases would still result from natural background sources. Consequently, non-point source problems from both man originated activities and natural background sources could stand in the way of achieving "water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water"[66] by 1983.[67]

Water quality planning and management under Section 208 of the Federal Water Pollution Control Act Amendments of 1972 is the primary vehicle for promoting control of non-point source pollution. Indeed, the first 109 planning agencies established under Section 208 identified urban stormwater and agricultural and construction runoff as principal sources of water quality problems, with many agencies indicating that urban runoff is the greatest single source of local and downstream pollution.[68]

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[64] Statement of Douglas Costle, Administrator, Environmental Protection Agency, before the Subcommittee on Oversight and Review, Committee on Public Works and Transportation, U.S. House of Representatives, July 18, 1979, pp. 8-11.

[65] U.S. Environmental Protection Agency, Methods for Identifying and Evaluating the Nature and Extent of Nonpoint Sources of Pollutants, EPA 430/9-73-014, October 1973, p. 1.

[66] Federal Water Pollution Control Act (FWPCA) Amendments of 1972, PL 92-500, 86 Stat. U.S.C., 1251(a).

[67] Council on Environmental Quality, Environmental Quality - 1978, U.S. Government Printing Office, Washington, D.C., December 1978, p. 118.

Across the country, non-point sources of pollution affect almost 90 percent of the EPA-designated hydrological drainage basins.[69] Pollution from agricultural activities and urban storm runoff (68 percent and 52 percent of the basins, respectively) is the most widespread, while pollution from construction activities is least widespread (Table 6-22). However, the concentration of different non-point sources varies considerably in the different parts of the country. For example, while surface waters in the North Central and South Central areas are highly affected by agricultural runoff, they are almost free from effect by construction or silvicultural activities.

In volume, the major pollutant from non-point sources is sediment (suspended solids and dissolved solids) from soil erosion, but many other pollutants produce problems in surface waters (Table 6-23). Indeed, problems from bacteria, oxygen depletion and nutrients are as widespread as those from suspended solids. Acidity (pH) problems affect almost 40 percent of the drainage basins in the Great Lakes area. Mining activities (notably metals mining) and urban runoff contribute to common problems with toxic materials 'n other parts of the country, and many agricultural areas have problems from pesticide pollution.

Cropland yields about 40 percent of the total sediment in inland waterways (Figure 6-13). However, construction and surface mining can yield large quantities of sediment per acre (about 10 times that produced per acre by cropland) in small areas (Table 6-24). Hence, sediment from these sources can have a very adverse localized impact on both water quality and costs of water supply and stormwater management. Well managed forests can be exceptionally free of erosion and sediment pollution, but soils in forests disturbed by natural disasters or by logging are erodible.[70] Together, logged and

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[68] Council on Environmental Quality, Environmental Quality - 1978, U.S. Government Printing Office, Washington, D.C., December, 1978, p. 118.

[69] U.S. Environmental Protection Agency, National Water Quality Inventory/1977 Report to Congress, EPA 440/4-78-001, October 1978, p. 15.

[70] U.S. Environmental Protection Agency, Methods for Identifying and Evaluating the Nature and Extent of Nonpoint Sources of Pollutants, EPA 430/9-73-014, October 1973, p. vii.

TABLE 6-22
DRAINAGE BASINS AFFECTED[a] BY NON-POINT SOURCES OF POLLUTION, BY TYPE OF NON-POINT SOURCE
1977

Geographical Region[b]	Number of Basins	Percent of Basins Affected				
		Urban Runoff[c]	Agriculture	Mining	Silviculture	Construction
Northeast	40	70	55	20	10	15
Southeast	47	57	62	15	30	2
Great Lakes	41	54	59	41	15	7
North Central	35	54	89	40	6	6
South Central	30	50	87	53	13	0
Southwest	22	23	73	36	5	0
Northwest	22	23	55	23	27	23
Islands	9	67	78	0	0	67
Total	246	52	68	30	15	9

[a] Basins where some (or all) stream segments have a problem with a pollutant that is not minor or insignificant, according to state officials.

[b] Note that the regional drainage basin groupings used here do not conform precisely to the 10 Federal Regions used in the discharge trends analyses.

[c] Does not reflect drainage basins affected by combined sewer overflows.

Source: U.S. Environmental Protection Agency, National Water Quality Inventory:1977 Report to Congress, EPA 440/4-78-001, Washington, D.C., October 1978, p. 15.

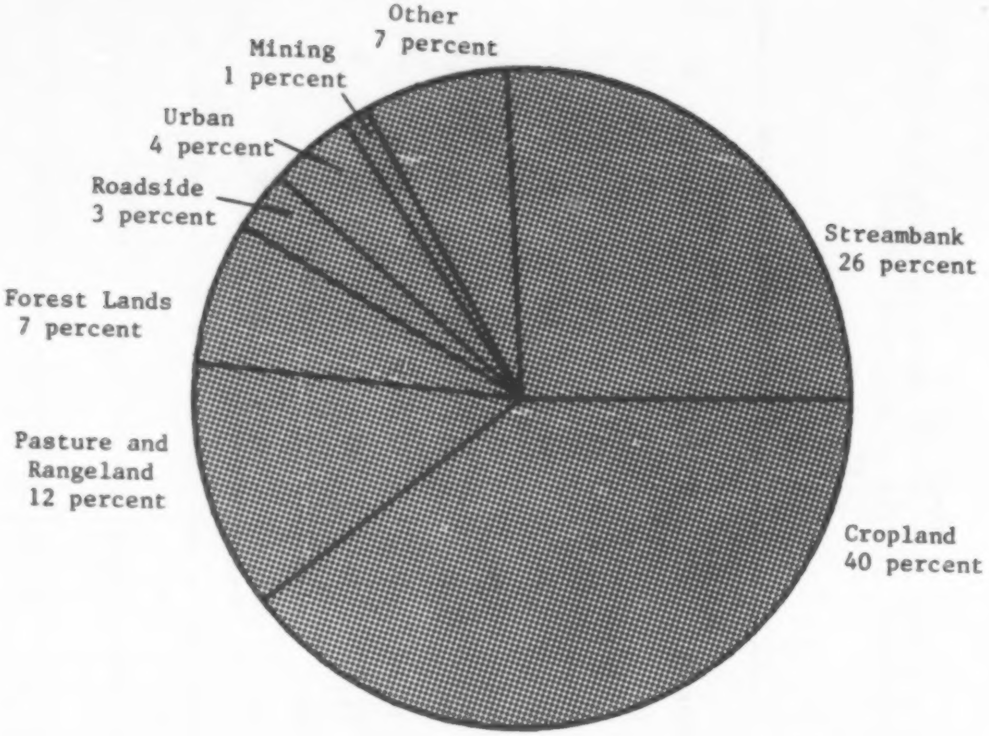
TABLE 6-23
DRAINAGE BASINS AFFECTED[a] BY NON-POINT SOURCES OF POLLUTION, BY TYPE OF POLLUTION PROBLEM
1977

Geographical Region[b]	Number of Basins	Percent of Basins Affected								
		Bacteria	Oxygen Depletion (BOD)	Nutrients	Suspended Solids	Dissolved Solids	pH	Oil and Grease	Toxics	Pesticides
Northeast	40	70	53	63	65	10	18	15	33	18
Southeast	47	66	74	57	34	4	9	4	11	23
Great Lakes	41	51	54	44	56	27	37	20	34	15
North Central	35	69	66	63	80	51	20	0	51	37
South Central	30	53	43	63	37	70	23	3	47	40
Southwest	22	36	14	45	32	68	14	14	27	0
Northwest	22	64	18	55	64	14	9	5	32	0
Islands	9	89	44	44	100	0	0	0	22	44
Total	246	61	51	56	54	30	18	9	32	22

[a] Basins where some (or all) stream segments have a problem (with the given pollutant) that is not minor or insignificant, according to state officials.

[b] Note that the regional drainage basin groupings used here do not conform precisely to the 10 **Federal** Regions used in the discharge trends analyses.

Source: U.S. Environmental Protection Agency, National Water Quality Inventory/1977 Report to Congress, EPA 440/4-78-001, Washington, D.C., October 1978, p. 16.



Source: U.S. Department of Agriculture, Soil Conservation Service, Environmental Impact Statement: Rural Clean Water Program, August 1978, p. 24.

FIGURE 6-13
ESTIMATED PERCENT OF SEDIMENT YIELD BY SOURCE
1977

TABLE 6-24
REPRESENTATIVE RATES OF EROSION FROM VARIOUS LAND USES

Land Use	Amount of Erosion (Tons/Square Mile/Year)	Rate of Erosion Relative To Forest = 1
Forest	24	1
Grassland	240	10
Abandoned Surface Mines	2,400	100
Cropland	4,800	200
Harvested Forest	12,000	500
Active Surface Mines	48,000	2,000
Construction	48,000	2,000

Source: U.S. Environmental Protection Agency, Methods For Identifying and Evaluating the Nature and Extent of Nonpoint Source of Pollutants, EPA 430/9-73-014, Washington, D.C., October 1973, p. 6.

unlogged forest land is estimated to yield less than 10 percent of the total sediment. As a result of sediment deposition, many harbors and rivers become severly clogged and require dredging. Disposal of this dredged material (which requires a permit issued under Section 404 of the Federal Water Pollution Act), produces ocean pollution problems as well (see Section 9.3 for further discussion).

Two major sources of non-point source water pollution, urban runoff and agricultural runoff, are discussed in detail in this section. Other non-point sources are included but releases are not projected, as the SEAS model does not yet have this capability.

Relevant Scenario Assumptions

For both High Growth and Low Growth Scenarios, projections of non-point source pollution deal with gross discharges of various pollutants. In urban runoff, this refers to discharges that would occur in the absence of any control and corrective measures, such as Best Management Practices or conventional storage and treatment practices. In agricultural runoff, this refers to discharges that would occur in the absence of additional soil conservation measures, such as more extensive use of BMP's, and significant changes in the current trends in fertilizer and pesticide use. Net discharges (i.e., expected discharges after corrective and control measures are applied) are not discussed in detail because the extent to which these types of controls will be applied is difficult to foresee, and because the degree of control varies both across urban areas and across crop production systems and geographic regions.

In addition, the gross discharge estimates for urban and agricultural runoff do not reflect just the incremental increases in releases as a result of man's activities on urban and rural areas; that is, non-point releases that would have commonly occurred (i.e., the natural background releases if the land had not been disturbed) have not been deleted from the projections because the discharge trends are most meaningful when they reflect releases given existing land use activities.

Trends in gross pollutant discharges from 1975 to 2000 for urban and agricultural runoff are assumed to be largely a function of population growth and economic activity. Variations in pollutant discharges between scenarios can be tied solely to differing assumptions about population growth and economic activity, since all other assumptions are the same in both scenarios. Methods and scenario assumptions are discussed in more detail in the introductions to urban and agricultural runoff.

Data Sources and Quality

The introductory sections to urban and agricultural runoff provide detailed information about the data sources and the quality of the data used in each projection method. The methods used in projecting gross non-point pollutant runoff represent the state-of-the-art in modeling urban and agricultural runoff. These projections are approximations of what pollutant releases may be like in the future; they are not intended as precise forecasts. The amounts in these projections may differ from some other estimates, but the regional distribution and trends in discharges are believed, in any case, to represent a reasonable picture of urban and agricultural runoff.

Organization of Discussion

The next sections discuss urban runoff (Section 6.3.2) and agricultural runoff (Section 6.3.3). In each section, an introduction describes the type of problem that exists, the major pollutants, the control and corrective measures available, and the method used to project discharge trends. The scenario assumptions relating to the discharge trends are presented and the accuracy of the projections is assessed. National and regional discharge trends are then presented. For urban runoff, all pollutants are discussed together; for agricultural runoff, the discussion is divided into sediments, nutrients, and pesticides. Toxic pollutants are not included in either the urban or agricultural runoff trends because of data deficiencies described in Section 6.2.1.

In Section 6.3.4, other non-point sources (mining, silviculture, and construction) are discussed in somewhat less detail. Problems and the major pollutants associated with each activity are presented, and the effect of these activities on current water quality--that is, where these activities are currently causing concern--is described.

6.3.2 Urban Runoff

HIGHLIGHTS OF SECTION 6.3.2

- Urban runoff is a significant factor in the degradation of our nation's waters, affecting half of all drainage basins.

- Discharges from urban sources (including combined sewer overflows, storm sewered runoff, and unsewered stormwater runoff), in the absence of controls, are projected to increase between 1975 and 2000.

- The Southeast and South Central Regions (Federal Regions IV and VI), which are projected to have the greatest increases in population, are also projected to have the greatest increases in urban pollutant discharges.

- The regional distribution of urban pollutant discharges varies because of population density, urban land use types, precipitation patterns, and area served by different types of sewer systems. The Great Lakes Region (Federal Region V) contributes about 25 percent of the pollution, the Southeast and New York-New Jersey Regions (Federal Regions IV and II) together about 30 percent, but the drier, less urbanized Mountain Region (Federal Region VIII) contributes only 1 percent.

Introduction

Urban rainfall runoff has been cited as a cause of degraded water quality in populous areas and contains almost all types of pollutants. Suspended sediments and toxic substances, particularly heavy metals, cause the most harm, but bacteria, oxygen-demanding materials, nutrients, and oil and grease are also problems.[71]

Pollutants in urban stormwater runoff come from air pollutants that settle in streets, organic debris, animal wastes, and discarded litter[72]--materials that defy efforts at measurement, or even at estimation of magnitude. For example, it was estimated in the 1976 National Residuals Discharge Inventory that urban runoff (including combined overflows) generated about 1.7 million tons of biochemical oxygen demand and about 30 million tons of total suspended solids (TSS) annually; however, it was noted that those estimates may err by at least one order of magnitude.[73]

Across the country, about half of the drainage basins are now polluted by urban runoff (Figure 6-14). The highest percentage of affected basins (about 70 percent) is in the densely populated New England, New York-New Jersey, and Middle Atlantic Regions (Federal

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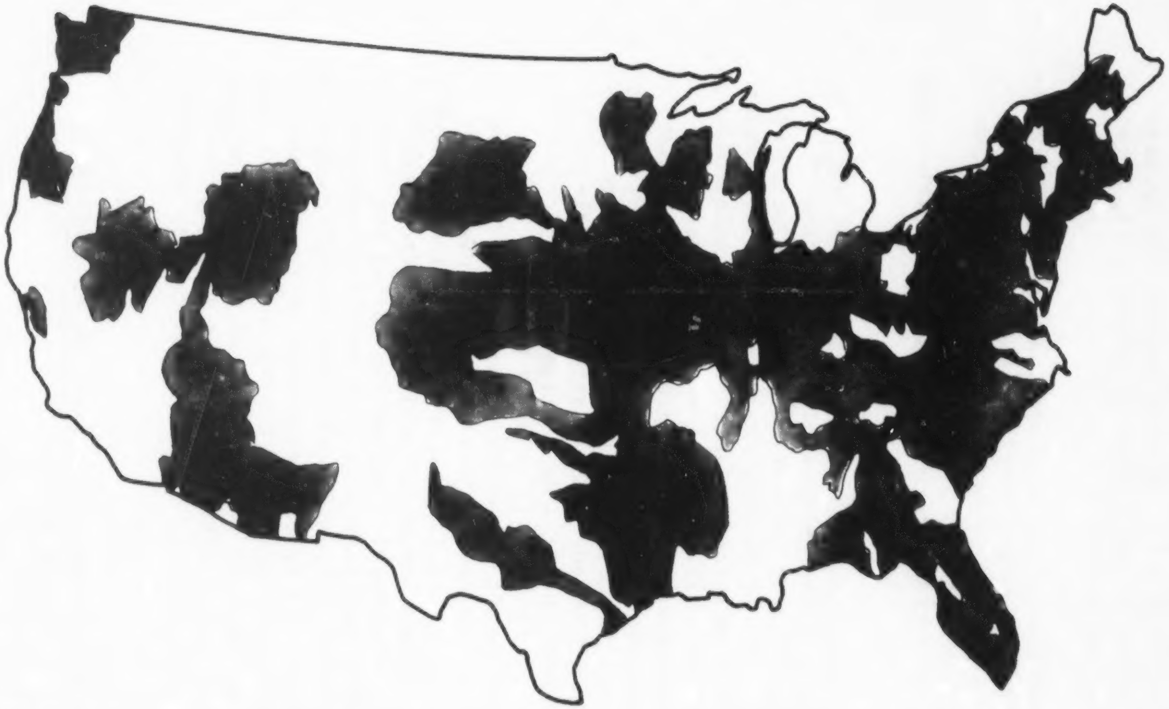
[71] U.S. Environmental Protection Agency, National Water Quality Inventory/1977 Report to Congress, EPA-440/4-78-001, October 1978.

[72] Midwest Research Institute, Loading Functions for Assessment of Water Pollution From Nonpoint Sources, EPA 600/2-76-151, prepared for and published by the U.S. Environmental Protection Agency, Office of Research and Development, May 1976, p. 186.

[73] Luken, R.A., D.J. Basta, and E.H. Pechan, The National Residuals Discharge Inventory, prepared by the National Research Council for the National Commission on Water Quality, Washington, D.C., January 1976, pp. 99-102.



NOTE: Basins where some (or all) stream segments have a problem with urban runoff that is not minor or insignificant, according to state officials. Affected basins are shaded. Does not reflect basins affected by combined sewer overflows.

Source: U.S. Environmental Protection Agency, National Water Quality Inventory: 1977 Report to Congress, EPA 440/4-78-001, Washington, D.C., October 1978.

FIGURE 6-14
EPA-DESIGNATED HYDROLOGICAL DRAINAGE BASINS AFFECTED BY POLLUTION FROM URBAN RUNOFF
1977

Regions I, II, and III); the lowest percentage (about 25 percent) is in the West and Northwest Regions (Federal Regions IX and X). In the Great Lakes Region (Federal Region V), which generated the largest proportion--about one-fourth--of gross urban runoff in 1975, more than half of the basins are affected.[74]

Control of urban runoff does not fall under any specific EPA effluent guidelines, but combined sewer overflows and storm sewer discharges in urban areas are subject to National Pollution Discharge Elimination System (NPDES) permits.[75] Thus, once urban runoff enters the sewer collection system, it must meet any applicable NPDES requirements.

Various control and corrective measures--nonstructural and structural--can be utilized to reduce urban runoff pollution.[76] Best Management Practices focus on prevention and include measures such as land use planning, use of natural drainage features, erosion controls, street repair and sweeping, collection system maintenance, control of litter, use of detention ponds, and onsite storage for runoff. Structural alternatives comprise conventional wastewater treatment practices, including primary treatment devices (swirl concentrators, microstrainers, dissolved air flotation, sedimentation), secondary treatment devices (contact stabilization, physical-chemical), and high- and low-density area reservoirs.

Because sewered urban runoff is usually concentrated when the first appreciable amount of rainfall occurs in a storm event (that is, the "first flush" effect), and is released from a finite set of discharge points, a significant amount of pollution control can, in theory, be achieved using structural alternatives during the "first flush." Nevertheless, BMP's are generally preferred to structural alternatives (both for sewered and unsewered urban runoff) because of lower costs, faster results, and better protection of the environment. However, the greatest difficulty in trying to use them is that it is almost impossible to quantify the benefits of a particular control measure. It is clear that onsite storage, for example, can reduce downstream conduit requirements, but the water quality benefits are far less defined. For BMP's to be effective, they would need to be used on a large scale basis.[77]

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[74] U.S. Environmental Protection Agency, National Water Quality Inventory: 1977 Report to Congress, EPA 440/4-78-001, October 1978, p. 16.

[75] U.S. Environmental Protection Agency, Office of Water Program Operations, 1976 Needs Survey: Cost Estimates for Construction of Publicly-Owned Wastewater Treatment Facilities, EPA 430/9-76-010, February 1977.

[76] Metcalf and Eddy, Inc., Urban Stormwater Management and Technology: Update and User's Guide, EPA 660/8-77-014, 1977, pp. 12-13.

The method used here to estimate gross urban pollutant runoff was developed by James Heany and others at the University of Florida.[78] For this analysis, urban non-point source water pollution refers to wet weather pollutant discharges from combined sewers, storm sewers, and the unsewered portions of urban areas. Although pollutant discharges from combined sewers and storm sewers are technically considered to be point sources (see Sections 6.1 and 6.3.1), they are included in this discussion because municipal point source releases (see Section 6.2) do not reflect combined sewer overflows or storm sewer discharges. Pollution from urban construction is not included in the discharge estimates.

As applied here the model accounts for regional differences in population density, urban land use types, precipitation patterns, and types of sewer systems, but does not accommodate changes over time. The projections of urban runoff (1975, 1985, 1990, and 2000) are assumed to be a function of expected land area expansion in each urban area. Since each urban area's population density is assumed to remain the same, urban land area expands at the same rate as population; consequently, the percent change in each pollutant in each urban area is assumed to equal the percent change in population in each urban area.

Because projections of urban runoff are so directly related to population growth in each urban area, a restatement of the scenario assumptions on population growth, given in Chapter 2, is appropriate:

- In the High Growth Scenario, total population is expected to increase about 20 percent, from 213 million in 1975 to 262 million by 2000. In the Low Growth Scenario, population is assumed to increase more slowly, reaching 245 million by 2000.

- In both scenarios, most of the total population increase is expected to occur between 1975 and 1990; a lower annual population increase is assumed for 1990 to 2000.

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[77] Metcalf and Eddy, Inc., Urban Stormwater Management and Technology: Update and User's Guide, EPA 600/-77-014, 1977, pp. 12-13.

[78] Heany, J. et al., Nationwide Evaluation of Combined Sewer Overflows and Urban Stormwater Discharges, Volume II: Cost Assessment and Impacts, EPA 600/2-77-064, March 1977.

- The relative regional population growth rates for urban areas are assumed to be the same for both scenarios.

It should be noted that some of the data needed to use the model may be erroneous.[79] Forecasts of the model's principal explanatory variable, population, would be affected if regional migration patterns differed from those we assumed. Land use data needed to calibrate the model are available for only a few cities, so it is assumed that the distribution of land uses is the same everywhere. No changes in land use are forecast because of uncertainties about future industrial relocations. Possible long-term cyclical patterns of rainfall could affect runoff but are not included in the precipitation data, which reflect historical averages. Urban runoff quality data (i.e., pollutant loading rates) are available for only a few cities and reporting is not always consistent.

Comparison of the SEAS gross urban pollutant discharge projections with other estimates of urban pollution,[80] shows that the SEAS projections are substantially lower, by a factor of two to five. However, these other estimates are not necessarily precise; it was noted earlier that the National Residuals Discharge Inventory estimates may err by at least one order of magnitude.

Although firm data on discharges from urban runoff are not available, the SEAS discharge estimates presented below can be viewed as reasonable indicators of trends, if not magnitudes of pollutant releases from urban runoff. Because we know that urban runoff is a major factor in the degradation of the nation's surface waters, the regional distribution and trends in these discharges from 1975 to 2000 are of greater importance than actual tonnage estimates for understanding where urban runoff may cause additional water quality problems in the future.

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[79] The model's data base is periodically improved as new data become available.

[80] Luken, R.A., D.J. Basta, and E.H. Pechan, The National Residuals Discharge Inventory, prepared by the National Research Council for the National Commission on Water Quality, Washington, D.C., January 1976, pp. 99-102. Also, Midwest Research Institute, National Assessment of Water Pollution From Nonpoint Sources, Draft of Final Report prepared for the U.S. Environmental Protection Agency, Contract Number 68-01-2293, November 1975, p. 16.

Discharge Trends for Urban Runoff

General Trends. Estimates of gross discharges for seven major water pollutants in urban runoff are shown in Table 6-25 for 1975, 1985, 1990, and 2000. In the High Growth Scenario, this pollution is expected to increase by about 20 percent from 1975 to 2000. Most of the increase is projected to occur between 1975 and 1990 because of the higher annual population increase assumed for that period. Gross urban runoff pollutant discharge estimates increase at the same rate for all pollutants because they are all calculated as a direct function of population growth.

In the Low Growth Scenario, urban runoff pollution is projected to increase by 14 percent from 1975 to 2000. Thus, a slightly lower rate of population growth does not produce significant differences between scenarios in projected pollutant discharges.

Analysis of Trends. In 1975, the Great Lakes Region (Federal Region V) contributed one-fourth of the gross pollution due to urban runoff, and the New York-New Jersey and Southeast Regions (Federal Regions II and IV) together contributed almost one-third (Figure 6-15). In contrast, very little of the gross urban runoff--about 1 percent--was generated in the drier, less urbanized Mountain Region (Federal Region VIII). Regional differences result from variations in the distribution of urban populations and urban land areas, and differences in precipitation and in areas served by sewer systems.

From 1975 to 2000, regional growth rates of gross urban runoff discharges reflect projected differences in the urban population growth rates (Figure 6-16). These differences, however, do not alter the regional distribution because most regional growth rates are not projected to be much different than the national growth rate. Furthermore, because the same relative regional growth rates for urban areas are assumed, the regional distribution of gross urban runoff is the same for both scenarios by 2000. In the High Growth Scenario, gross discharges are projected to increase most rapidly in the Southeast Region (Federal Region IV) and least rapidly in the New York-New Jersey, Great Lakes, and Central Regions (Federal Regions II, V, and VII).

If Best Management Practices and storage and treatment control practices utilized during the "first flush" of a storm event could uniformly reduce pollutant releases from urban runoff by 10 percent across the country by 2000, three regions (Federal Regions II, V, and VII) in the High Growth Scenario and five regions (Federal Regions I, II, III, V, and VII) in the Low Growth Scenario would discharge less in 2000 than in 1975. A 25 percent reduction in pollutant discharges by 2000 would stop the increase in releases in all but two regions

TABLE 6-25
TRENDS IN GROSS DISCHARGES OF MAJOR WATER POLLUTANTS IN URBAN RUNOFF[a]
(THOUSANDS OF TONS)

		High Growth			Low Growth		
Pollutant	1975	1985	1990	2000	1985	1990	2000
Biochemical Oxygen Demand	370	400	420	450	390	400	420
Chemical Oxygen Demand	3,400	3,400	3,900	4,200	3,600	3,800	3,900
Suspended Solids	6,300	6,800	7,100	7,600	6,500	6,900	7,100
Dissolved Solids	4,000	4,400	4,600	4,900	4,300	4,400	4,600
Phosphorus	5	5	6	6	5	5	6
Nitrogen	58	63	65	70	61	63	65
Oil and Grease	86	94	98	110	92	95	98

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[a] These discharges may uniformly be too low by a factor of two to five; see introduction to Section 6.3.2.

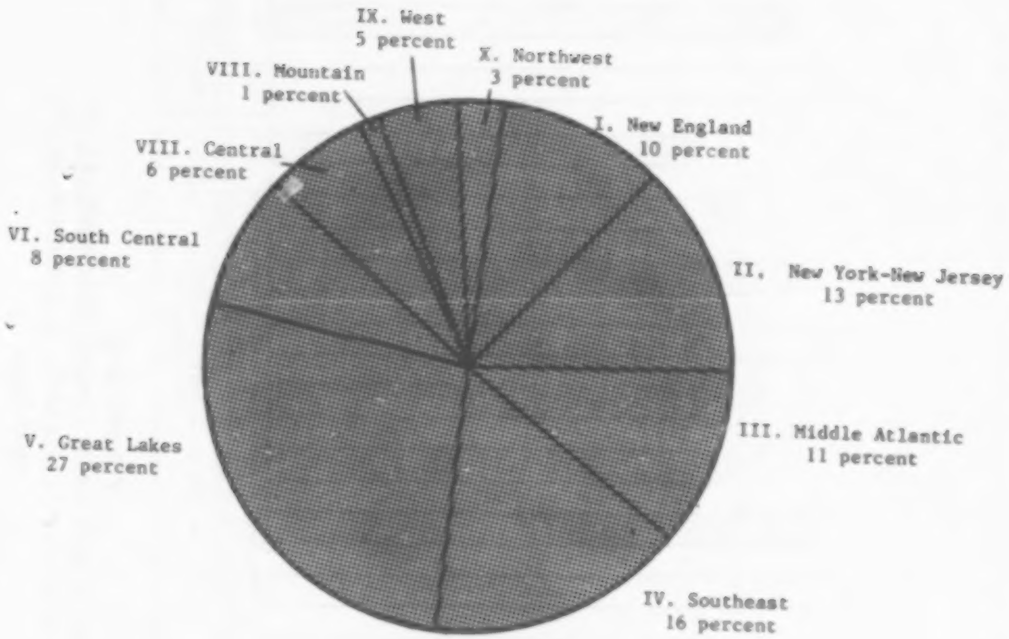

FIGURE 6-15
REGIONAL DISTRIBUTION OF GROSS DISCHARGES OF MAJOR WATER POLLUTANTS IN URBAN RUNOFF
1975

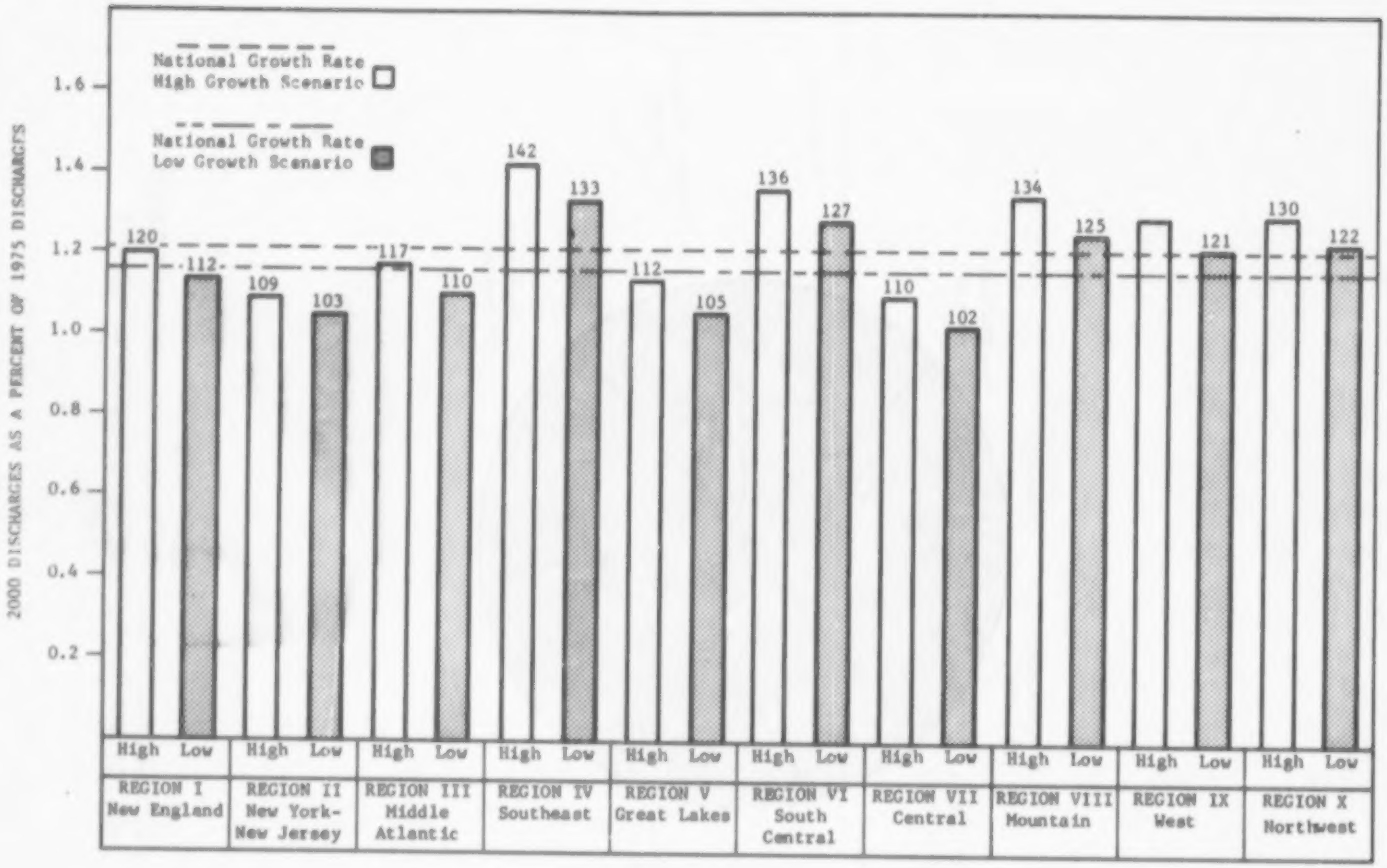

FIGURE 6-16
CHANGE IN REGIONAL GROSS DISCHARGES OF MAJOR WATER POLLUTANTS IN URBAN RUNOFF
1975-2000

(Federal Regions IV and VI) in the Low Growth Scenario, but only half the regions (Federal Regions I, II, III, V, and VII) in the High Growth Scenario. For pollutant releases to be lower by 2000 in all regions regardless of scenario, a 30 to 45 percent reduction in pollutant discharges would have to be accomplished in certain regions (Federal Regions IV, VI, VIII, IX, and X).

6.3.3 Agricultural Runoff

HIGHLIGHTS OF SECTION 6.3.3

- o Agricultural activities are the most widespread cause of non-point source pollution in the United States, affecting two-thirds of all drainage basins.
- o In the absence of improved and more widespread use of conservation practices, national annual discharges of all agricultural pollutants, except miscellaneous pesticides (fumigants, desiccants, and rodenticides), are projected to increase from 1975 to 2000. Miscellaneous pesticide releases are expected to decline, primarily due to decreased use per acre on tobacco.
- o The distribution of agricultural pollutant discharges varies among regions, mainly because of differences in crop production and precipitation patterns. The Southeast, Great Lakes, and Central Regions (Federal Regions IV, V, and VII) generate more than three-fourths of most pollutant releases; however, insecticide and miscellaneous pesticide releases are important in the South Central Region (Federal Region VI) and fungicide releases are greatest in the Northwest Region (Federal Region X).
- o Corn and soybean production accounts for most agricultural pollutant releases; however, cotton production contributes heavily to insecticide releases, potato production to fungicide releases, and tobacco production to miscellaneous pesticide releases.
- o If Best Management Practices were widely adopted by farmers, all regions would be expected to discharge less sediment by 2000 than in 1975; reductions would be greatest, relatively, in the Mountain Region (Federal Region VIII).

Introduction

In rural areas, agriculture--including non-irrigated and irrigated crop production and animal production--is the main non-point source of water pollution. In 1975, over 1,250 million acres of land were devoted to agriculture, with almost 390 million acres used for crop production.[81] By disturbing the vegetative cover and loosening the soil, farming can cause erosion and add sediments to streams. Increasing use of fertilizers and pesticides raises the potential for pollution of both ground and surface waters.

The release and runoff of pollutants from farmlands is governed mainly by local factors: precipitation, wind, the overland flow of water, soil characteristics, geology, vegetation, and topography. Consequently, the runoff of pollutants from farmlands is subject to sharp and unpredictable variations, and differs among agricultural activities.

The pollutants that generally result from non-irrigated crop production are sediments, nutrients, and pesticides; organics, such as crop residue, can also result. Sediment, defined as fragmented minerals or organic matter eroded from the soil, is the largest single pollutant that affects water quality. Deposited in water bodies, it can ruin fish spawning areas, clog river channels, coat lake bottoms, and release adsorbed pesticides and nutrients to the water.

Annual sheet and rill erosion in the contiguous United States from cropland, pastureland, and rangeland has recently been estimated by the Soil Conservation Service at about 3.7 billion tons, with a little more than half attributable to cropland production.[82] It has been further estimated that about half of all eroded soil washes into streams and one-fourth reaches tidal waters.[83] Thus, the estimated sediment yield from cropland to surface waters is currently about 1 billion tons per year, which is not far removed from an estimate made by the Soil Conservation Service 10 years ago.[84]

Nutrients are a particular pollution problem in intensely farmed regions, where concentrations of nitrogen and phosphorus in streams may be higher than anywhere except rivers receiving heavy municipal waste loads.[85] Although commercial fertilizers are a major source of nutrients, they are not the only source nor always the most important one; this is particularly true for nitrogen releases. Nationally, commercial fertilizers have been estimated to account for only about half of the nutrients on cropland, with biological fixation, animal manure, plant residues, and precipitation contributing the other half.[86] High concentrations of some discharged nutrients in water may be toxic to human beings or animals; however, the principal problem caused by discharged nutrients is accelerated eutrophication of water bodies.

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[81] Thronson, R.E., Nonpoint Source Control Guidance: Agricultural Activities, EPA 440/3-78-001, February 1978, p. 0-1.

[82] U.S. Department of Agriculture, Soil Conservation Service, National Resource Inventories-1977, December 1978 (unpublished data).

[83] Holeman, J.N., "Procedures Used in the SCS to Estimate Sediment Yield," paper presented at the Sediment Yield Workshop, Oxford, Mississippi, November 1972.

[84] U.S. Department of Agriculture, Conservation Needs Inventory Committee, National Inventory of Soil and Water Conservation Needs, 1967, Statistical Bulletin No. 461, January 1971.

Pesticides that have been applied on cropland can run off in solution, or may be adsorbed by soil particles and carried to receiving waters where they can have significant effects. Generally, no more than 5 percent of applied pesticides find their way into surface waters,[87] but many pesticides are highly toxic and persistent in fish and other aquatic species. Pesticides can accumulate in predatory species, becoming much more concentrated in their tissues than in the water. For many pesticides, even small discharges therefore must be considered significant.

Organic pollutants from crop residue and other materials carried to surface waters can exert a high biochemical oxygen demand and may deplete the supply of oxygen enough to kill some forms of aquatic life.

The types of non-point source pollutants are the same for irrigated as for non-irrigated crop production. However, the addition of irrigation water increases the potential for pollution by salinity, sediments, and other pollutants associated with sediments. These problems primarily arise in the 17 western states where irrigation is most widely used for crop production.

Animal production--both confined[88] and pastured--can produce water pollution problems as well. About 2 billion tons of livestock wastes are produced annually. As much as half of these wastes may be produced in confined facilities. While most of these waste materials are collected and spread on farm acreage, runoff and seepage pose a pollution hazard. The principal pollutants produced are nutrients, organic matter, and, for pastureland, sediments. Nutrient releases from animal production have been estimated elsewhere to be at least as great as nutrient releases from crop production.[89]

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[85] Council on Environmental Quality, Environmental Quality - 1978, U.S. Government Printing Office, Washington, D.C., December 1978, p. 122.

[86] U.S. Environmental Protection Agency and United States Department of Agriculture, Control of Water Pollution From Cropland: Volume II: An Overview, EPA 600/2-75-026(b), June 1976, p. 61.

[87] Ibid.

[88] Concentrated confined animal production operations are subject to National Pollutant Discharge Elimination Systems (NPDES) permits and are thus considered point sources as defined in Title 40, Parts 124 and 125 of the Code of Federal Regulations, printed in the Federal Register, Volume 41, No. 54, pp. 11458-11461, March 18, 1976.

Farming and related activities are the most widespread cause of non-point source water pollution problems. Almost 70 percent of the EPA-designated hydrological drainage basins in the United States are thought to be affected (in whole or in part) by agricultural runoff, with a very even geographic distribution of affected basins (Figure 6-17). The South Central, Central, and Mountain Regions (Federal Regions VI, VII, and VIII) are affected the most--with almost 90 percent of drainage basins polluted--while the New England, New York-New Jersey, Middle Atlantic, and Northwest Regions (Federal Regions I, II, III, and X) are affected the least--with about 55 percent of the drainage basins polluted.

Non-point source water pollution from agricultural activities can be controlled most effectively at the source through the use of Best Management Practices. For crop production, in particular, proper land use and agricultural management practices are the key to protecting water quality.

Erosion, and hence sediment loads, can be reduced by use of terraces, diversions, strip cropping, contouring, grassed waterways, and/or crop rotations. Nutrient releases can be reduced if fertilizer applications are properly planned and carried out. For example, alternating production of nitrogen-fixing crops with crops requiring heavy fertilization can substantially reduce the long-term average quantity of nitrogen that must be applied to soil.[90]

For pesticides, as with nutrients, BMPs must include consideration of timing, type, amount, and method of application. These control measures can be used in conjunction with "integrated pest management," which attempts to minimize the use of chemical pesticides through crop rotation, mechanical measures to remove food for pests, biological controls (fungus-coated seeds or predator insects), insect sterilization, use of natural toxins and insect attractants, and development of disease-resistant crops.[91]

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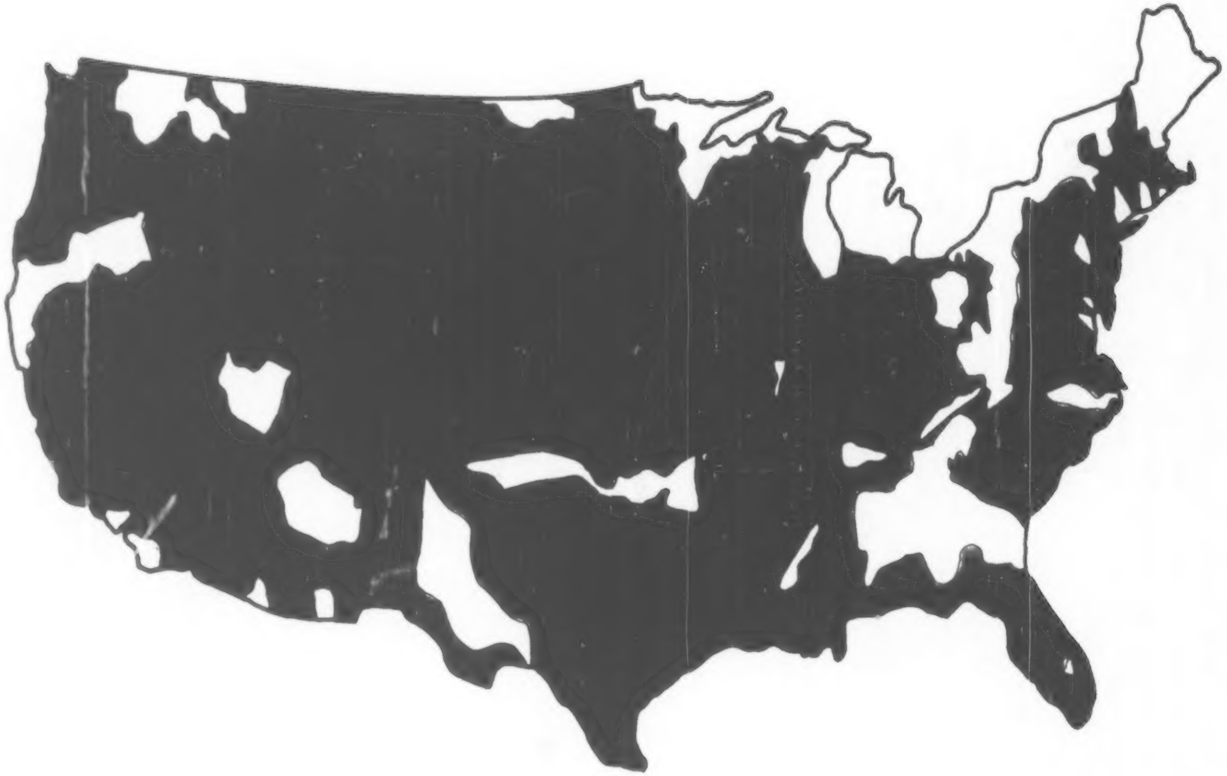
[89] Thronson, R.E., Nonpoint Source Control Guidance: Agricultural Activities, EPA 440/3-78-001, February 1978, p. 0-2.
[90] Ibid, Chapter 3.
[91] Ibid.



NOTE: Basins where some (or all) stream segments have a problem with agricultural runoff that is not minor or insignificant, according to state officials. Affected basins are shaded.

Source: U.S. Environmental Protection Agency, National Water Quality Inventory/ 1977 Report to Congress, EPA 440/4-78-001, Washington, D.C., October 1978, p. 17.

FIGURE 6-17
EPA-DESIGNATED HYDROLOGICAL DRAINAGE BASINS
AFFECTED BY POLLUTION FROM AGRICULTURAL ACTIVITIES
1977

The particular Best Management Practices to be used depend on the physical, climatological, and managerial conditions under which non-point source pollution occurs. The effect of BMP's on agricultural non-point source pollution is highly variable from crop to crop and from locality to locality.[92] Thus, it is not easy to generalize about reductions in sediment and other pollutant loads to be expected from the adoption of BMP's since the efforts of using BMP's on pollutant loads are so site specific.

This agricultural trends analysis is limited to discharges resulting from the production of eight major crops: corn, cotton, soybeans, wheat, tobacco, potatoes, citrus fruit, and apples.[93] These eight crops have accounted in the past for only about half of all crop acreage, but about 80 percent of crop acreage receiving pesticides and fertilizers.[94] The discharge estimates presented here are also a function of rainfall only and, hence also do not include the effects of irrigation water returns or wind erosion,[95] nor are the effects of animal production included.

Our projections of anticipated pollutant releases assume that the proportion of cropland treated for soil conservation is constant over the projection period and has not changed from the proportion of the late 1960's.

Moreover, continuation of current trends in pesticide and fertilizer use is assumed. In addition, although it is generally expected that BMPs will become more widely used in coming years[96]

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[92] Thronson, R.E., Nonpoint Source Control Guidance: Agricultural Activities, EPA 440/3-78-001, February 1978, p. 0-2.

[93] Only these crops are included in the analysis because crop production forecasts supplied by the economic module of SEAS are limited to these crops.

[94] See: U.S. Department of Agriculture, Agricultural Statistics (various years); USDA Fertilizer Situation Report (various years); and USDA, Farmer's Use of Pesticides (various years).

[95] Wind erosion is generally a minor problem in water pollution, compared to water erosion. However, it contributes to air pollution in arid and semi-arid areas. (See: U.S. Environmental Protection Agency, Methods and Practices for Controlling Water Pollution From Agricultural Nonpoint Sources, EPA 430/9-73-015, October 1973, p. 25.)

[96] Development Planning and Research Associates, Inc., Environmental Implications of Trends in Agriculture and Silviculture - Volume I: Trend Identification and Evaluation, EPA 660/3-77-121, October 1977, p. 44.

(particularly since the U.S. Department of Agriculture, under the Rural Clean Water Program,[97] will provide 50 percent funding for agricultural practices to reduce soil erosion and improve water quality), it is difficult to qualify the effects of such practices (as indicated above). For this reason, indications of how BMPs may affect the sediment discharge trends are briefly discussed although not projected.

Ten pollutants, grouped as sediment, nutrients, and pesticides, are included in the analysis. The measures of sediment pollution are total suspended solids, total dissolved solids, and biochemical oxygen demand. The three major plant nutrients analyzed are nitrogen, phosphorus, and potassium. Pesticides treated include the three principal categories--herbicides, insecticides, and fungicides--as well as miscellaneous pesticides (fumigants, defoliants, desiccants and miticides).

Forecasts of agricultural runoff are made for the years 1985, 1990, and 2000. The method employed combines the results of SEAS economic projections, Department of Agriculture data, surface runoff estimates, and application rates of fertilizers and pesticides.

Specifically, the factors considered in the projections include: crop production forecasts (projected within the economic module of SEAS); agricultural crop yield forecasts (from USDA[98]); average annual erosion estimates per acre by crop and soil type (calculated based upon rainfall),[99] soil erodibility and topography,[100] crop management factors,[101] and conservation practices[102] using the

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[97] Authorized by Section 208(j) of the FWPCA, as amended by section 35 of the Clean Water Act of 1977 (PL 95-217).

[98] U.S. Department of Agriculture, Soil Conservation Service, National Interregional Agricultural Projection System (the projections used were those developed in 1976 for a study for Resources For the Future--USDA, ERS, Food and Agriculture, February 1977, Washington, D.C.).

[99] U.S. Department of Agriculture, Soil Conservation Service, Procedures for Computing Sheet and Rill Erosion in Project Areas, Technical Release 51, Revision 2, September 1977.

[100] U.S. Department of Agriculture, Soil Conservation Service, Form I and IW Questionnaire, unpublished survey data on erosion characteristics of various soil types, 1972.

[101] Midwest Research Institute, Loading Functions For Assessment of Water Pollution From Nonpoint Sources, EPA 600/2-76-151, prepared for and published by the U.S. Environmental Protection Agency, Office of Research and Development, May 1976.

[102] U.S. Department of Agriculture, Conservation Needs Inventory Committee, National Inventory of Soil and Water Conservation Needs, 1967, Statistical Bulletin No. 461, January 1971.

Universal Soil Loss Equation;[103] sediment delivery ratios (calculated based upon the size of the drainage area;[104] and pesticide and fertilizer application rates by crop based on projected trends from the U.S. Department of Agriculture.[105]

Agricultural land use (i.e., acres) required to meet production forecasts was calculated from agricultural yield forecasts. Agricultural land use forecasts were then coupled with the Universal Soil Loss Equation to predict soil loss estimates, which were then translated into sediment loads (i.e., soil delivered to surface waters) by means of the sediment delivery ratios. Sediment was expressed as suspended and dissolved solids. BOD releases to surface waters were based on sediment loads.

Pesticide and nutrient releases were calculated on the basis of application rates, crop production forecasts, and agricultural yield forecasts. These data were converted into concentrations in the erodible soil layer and coupled with predicted soil erosion to estimate pesticide and nutrient transport to surface waters. Nutrient loads in the projections reflect the production of only four crops--corn, cotton, soybeans, and wheat--because projections of fertilizer application rates were unavailable for the other crops in this analysis. Projections of nutrient releases do not reflect nutrients from sources other than fertilizer, such as animal wastes, biological fixation, precipitation and plant residuals.

Other SEAS scenario assumptions that are important for the agricultural runoff projections include the following:

- Crop production projected within the economic module of SEAS is scenario-dependent; crop production in the High Growth Scenario is higher than in the Low Growth Scenario because of the higher population and economic growth assumptions of the High Growth Scenario.

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[103] Wischmeier, W.H. and D.C. Smith, Predicting Rainfall-Erosion Losses from Cropland East of the Rocky Mountains - A Guide for Selection of Practices for Soil and Water Conservation, Agricultural Handbook No. 282, 1965.

[104] U.S. Environmental Protection Agency, Methods for Identifying and Evaluating the Nature and Extent of Nonpoint Sources of Pollutants, EPA 430/9-73-014, October 1973, pp. 57-60.

[105] Fox, A., unpublished data used by USDA, ERS in a study for Resources For the Future (USDA, ERS, Food and Agriculture, Washington, D.C., February 1977). The application rates for pesticides and fertilizers are assumed to be the same in all regions, but vary among crops.

- The regional distribution of crop production is assumed to remain unchanged in both scenarios from 1975 to 2000.

- Trends in crop yields and pesticide and fertilizer application rates are assumed to be the same in both scenarios from 1975 to 2000.

- Soil loss per acre is scenario-independent and is assumed to remain constant over the 1975 to 2000 period.

SEAS projections cannot be directly compared with other data sources because of differences in coverage. SEAS includes only about 50 percent of all cropland (mostly row crops that are more susceptible to erosion than close-grown or orchard crops), while other sources have attempted to include all cropland or all agricultural land (that is, cropland, pasture land, and rangeland). Compared to the most recent Soil Conservation Service[106] estimates for all agricultural land and all cropland, the SEAS projections of gross sediment loss are necessarily low--by factors perhaps as large as 14 and 8, respectively--since the SEAS estimates do not include all agricultural land or even all cropland. However, even after adjustment is made for this difference in coverage, the SEAS projections of gross sediment loss, for the crops included in these projections, still appear to be much lower--by a factor of 4 or 5.

The basic cause for this difference rests in the sediment delivery ratios utilized in the SEAS analysis. Future SEAS work will incorporate improved estimates of soil loss per acre[107] as well as revised sediment delivery ratios. Therefore, at the present time, the SEAS projections should be regarded as being too low by a factor of 4 or 5 (if for the crops included in this analysis); 8 (if compared to estimates for all cropland); or 14 (if compared to estimates for all agricultural land).

An additional word is in order with respect to nutrient releases. Nutrient releases in SEAS do not consider nutrient sources other than commercial fertilizer use on four crops (corn, cotton, soybeans and wheat). Thus, the nutrient projections are not reflective of the total nutrient releases from the eight crops included in this analysis. Inclusion of nutrient releases from the use of fertilizers on the other four crops would not change the projections dramatically because these crops represent a small part (about 2 percent) of the combined cropland acreage for the eight crops. However, if the nutrient projections accounted for all nutrient sources (rather than simply commercial fertilizers), the discharge estimates would be considerably larger, by a factor greater than the factor of 4 or 5 cited above. Likewise, if the nutrient projections accounted for all nutrient sources and reflected releases from all cropland or agricultural land, the factors would again be much larger than the factors of 8 and 14 cited above.

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[106] U.S. Department of Agriculture, Soil Conservation Service, National Resource Inventories - 1977, December 1978, (data not yet accompanied by text and published).
[107] Ibid.

While the tonnage estimates are uncertain, the projections are meaningful for understanding where agricultural runoff may be of greater concern in the future. By focusing on the regional distribution and trends in pollutant discharges from 1975 to 2000, rather than on the actual tonnage estimates, one can identify the regions subject to possible further water quality degradation. It is in this light that the discharge trends should be viewed.

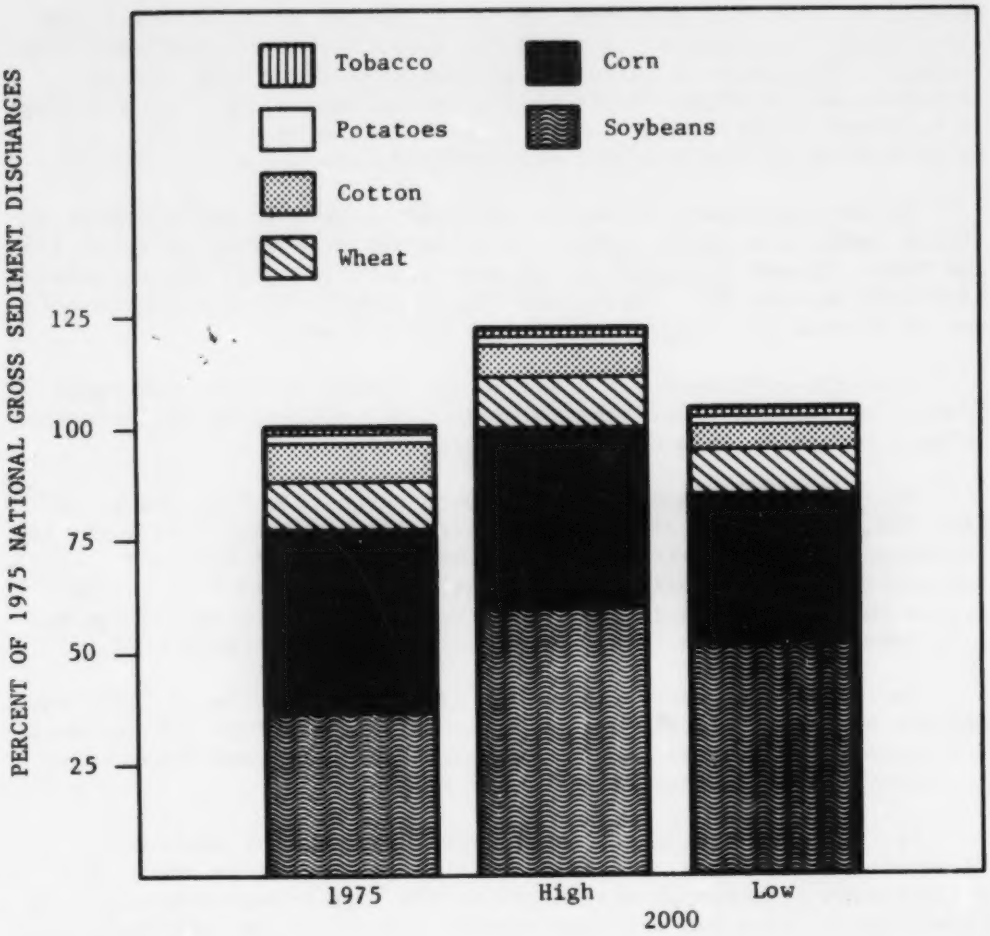
Sediment Discharge Trends

General Trends. In the High Growth Scenario from 1975 to 2000, annual gross discharges of sediments to surface waters (as measured by TSS, TDS, and BOD) are estimated to increase by about 20 percent (Figure 6-18 and Table 6-26). Since these discharges are directly

TABLE 6-26
TRENDS IN GROSS DISCHARGES OF SEDIMENT
IN AGRICULTURAL RUNOFF[a]
1975 AND 2000

Pollutant	1975 (10^3 Tons)	2000 (10^3 Tons) High Growth	2000 (10^3 Tons) Low Growth
Total Suspended Solids	94,000	110,000	97,000
Total Dissolved Solids	40,000	49,000	42,000
Biochemical Oxygen Demand	630	760	650

[a] These discharges may uniformly be too low by a factor of four or five. For assumptions included in these projections, see introduction to Section 6.3.3



NOTE: Crops contributing less than 0.5 percent are not shown. 1975 National Gross Sediment Discharges = 134 million tons (94 million tons of TSS and 40 million tons of TDS).

FIGURE 6-18
TRENDS IN GROSS DISCHARGES OF SEDIMENT IN AGRICULTURAL RUNOFF, BY CROP
1975 AND 2000

related to soil loss per acre, which is assumed to be constant over time, these increases would be wholly attributable to increased crop acreage. The greatest increases are expected for citrus fruits, soybeans, and potatoes (Table 6-27). A decline in total crop acreage is expected in cotton and tobacco. Corn and soybeans account for three-fourths of the sediment discharges during the entire period.

In the Low Growth Scenario, the lower growth in agricultural activity leads to a slower growth in pollutant discharges between 1975 and 2000. No net increase in sediment discharge is projected because increased acreage for citrus, apples, potatoes, and soybeans is offset by decreased acreage committed to other crops.

Scenario contrasts are greatest for cotton, potato, and apple production and least for tobacco production, reflecting differences between scenarios in demand for the eight crops.

Analysis of Sediment Trends. Since agricultural discharges of TSS, TDS, and BOD are estimated as a fraction of total soil loss, the projected regional distributions of these pollutants are identical to the distribution of soil loss, and the trends between 1975 and 2000 follow the trends in soil loss. Regional trends in crop acreage and soil loss for the High Growth Scenario are shown in Table 6-28.

In 1975, total crop acreage was greatest in the Great Lakes and Central Regions (Federal Regions V and VII). Soil loss and sediment discharges were greatest in the Central, Southeast, and Great Lakes Regions (Federal Regions VII, IV, and V).

By 2000, the Southeast, Great Lakes, and Central Regions (Federal Regions IV, V, and VII) would still contribute about 25 percent each of sediment discharges in the High Growth Scenario. In these regions corn and soybeans are the primary crops, and their production is expected to account for the bulk of regional sediment discharges by 2000 (Figure 6-19)--about 85 percent in Federal Region IV, 95 percent in Federal Region V, and 90 percent in Federal Region VII.

In the Low Growth Scenario, regional sediment discharges are generally not expected to increase significantly from 1975 to 2000 because regional crop acreage and soil loss do not increase much. The one exception is the Great Lakes Region (Federal Region V), where discharges of suspended and dissolved solids are projected to increase by about 20 percent. By 2000, the pattern of regional distribution is projected to be identical for both scenarios since the only distinction between them is lower total crop production in the Low Growth Scenario.

TABLE 6-27
TRENDS IN AGRICULTURAL ACTIVITY AND SOIL LOSS
1975 AND 2000

		High Growth		Low Growth		Scenario Difference[a] (Percent)
	1975	2000	Percent of 1975 Value	2000	Percent of 1975 Value	
Crop Production						
Cotton (10^6 lbs.)	5,570	5,910	106	4,860	87	-18
Corn (10^6 bu.)	6,570	9,730	148	8,430	128	-13
Soybeans (10^6 bu.)	1,710	3,360	212	3,080	180	-15
Wheat (10^6 bu.)	2,170	3,240	149	7,720	125	-16
Tobacco (10^6 lbs.)	2,220	2,070	93	1,940	87	- 6
Potatoes (10^6 cwt.)	340	580	171	480	141	-17
Citrus (10^6 tons)	16	37	231	32	200	-14
Apples (10^6 tons)	3	5	151	4	123	-18
Acres in Crop Production[b] (millions)	223	262	118	223	100	-15
Cotton	12.3	10.9	89	9.0	73	-18
Corn	76.1	74.0	97	64.1	84	-14
Soybeans	59.1	98.7	167	83.8	142	-15
Wheat	71.1	72.0	101	60.4	85	-16
Tobacco	1.1	0.8	72	0.7	67	- 6
Potatoes	1.3	2.0	145	1.6	121	-17
Citrus	1.3	3.2	241	2.8	207	-14
Apples	0.5	0.7	153	0.6	122	-20
Soil Loss (10^6 tons)	3,700	4,500	121	3,800	103	-15
Annual Average Soil Loss Per Acre (tons)[c]	17	17	100	17	100	0

[a] (Low Growth - High Growth) ÷ High Growth.

[b] In general, acreage increases are less than crop production increases due to assumed increases in agriculture yields from 1975 to 2000. Rounding may create inconsistencies in addition.

[c] Assumed to remain constant over time in both scenarios.

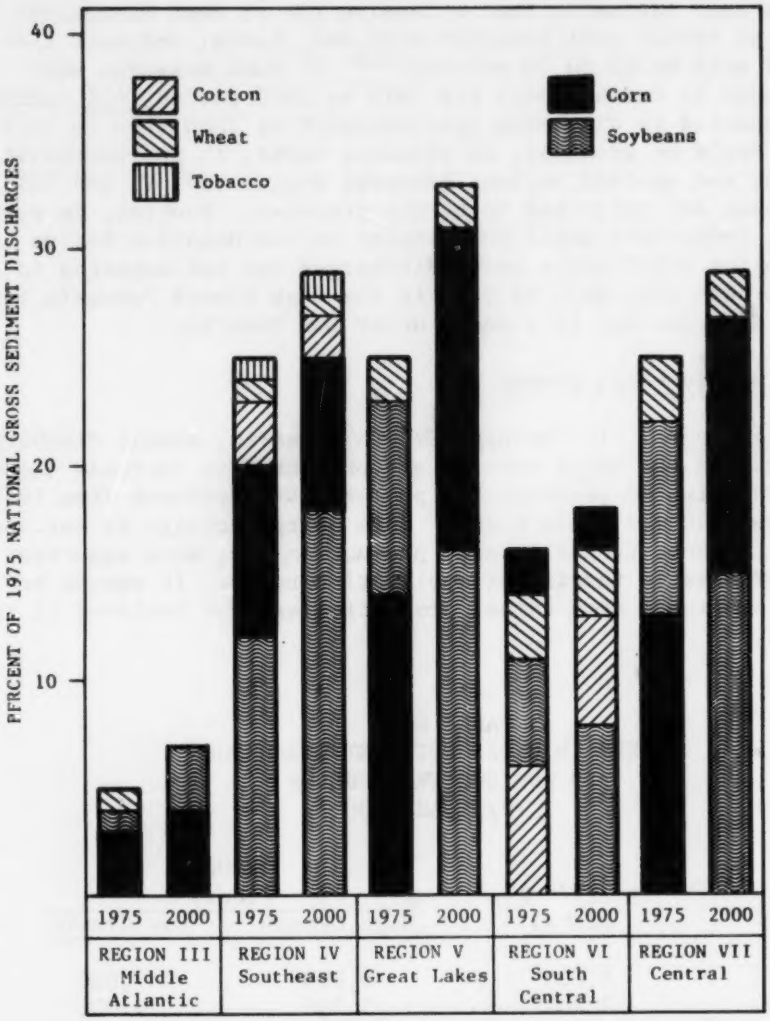
TABLE 6-28
TRENDS IN REGIONAL AGRICULTURAL ACTIVITY AND SOIL LOSS HIGH GROWTH SCENARIO 1975 AND 2000

	Acres in Crop Production				Soil Loss				
	1975		2000		1975		2000		
Region	Quantity (10^6 Acres)	Percent of National Total	Percent of 1975 Value	Percent of National Total	Quantity (10^6 Tons)	Percent of National Total	Percent of 1975 Value	Percent of National Total	Annual Average Soil Loss Per Acre (Tons)
I. New England	a	b	129	b	2	b	126	b	13
II. New York-New Jersey	1	1	119	1	17	b	120	b	14
III. Middle Atlantic	5	2	127	2	180	5	127	5	36
IV. Southeast	27	12	121	12	900	24	119	24	33
V. Great Lakes	65	29	132	33	880	24	136	27	14
VI. South Central	31	14	108	13	590	16	114	15	20
VII. Central	58	26	107	24	960	26	113	24	18
VIII. Mountain	26	12	105	10	72	1	100	2	3
IX. West	4	2	140	2	10	b	144	b	3
X. Northwest	7	3	129	3	86	2	129	2	13
Total[c]	223	100	118	100	3,700	100	121	100	17

[a] Less than 0.5 million acres.

[b] Less than 0.5 percent.

[c] Rounding may create inconsistencies in addition.



NOTE: Crops contributing less than 0.5 percent are not shown.
1975 National Gross Sediment Discharges = 134 million tons
(94 million tons of TSS and 40 million tons of TDS).

FIGURE 6-19
TRENDS IN REGIONAL GROSS DISCHARGES OF SEDIMENT
IN AGRICULTURAL RUNOFF, BY CROP
REGIONS III, IV, V, VI, AND VII
HIGH GROWTH SCENARIO
1975 AND 2000

It has been estimated that extensive use of Best Management Practices can reduce soil loss per acre and, hence, sediment discharges per acre by 30 to 50 percent.[108] If such measures were widely adopted by farmers over the 1975 to 2000 period, all regions would be expected to discharge less sediment by 2000 than in 1975. Reductions would be greatest, in absolute terms, in the Southeast, Great Lakes, and Central Regions (Federal Regions IV, V, and VII) where releases are projected to be the greatest. However, in relative terms, reductions would be greatest in the Mountain Region (Federal Region VIII) where gross discharges are not expected in any case to increase from 1975 to 2000 in the High Growth Scenario (and are expected to decline 15 percent under Low Growth).

Nutrient Discharge Trends

General Trends. In the High Growth Scenario, annual discharges of nitrogen from the crops covered are projected to increase about 55 percent, potassium 80 percent, and phosphorus 90 percent from 1975 to 2000 (Figure 6-20 and Table 6-29). This sharp increase in nutrient discharges reflects trends in crop production and, more important, assumed increases in fertilizer application rates. It should be noted that nutrients from animal production are not included in the projections.

TABLE 6-29
TRENDS IN GROSS NUTRIENT DISCHARGES
IN AGRICULTURAL RUNOFF
1975 and 2000

Pollutant	1975 (tons)	2000 (tons) High Growth	2000 (tons) Low Growth
Nitrogen	5,700	8,800	7,600
Phosphorus	3,000	5,700	4,900
Potassium	1,400	2,600	2,200
Total[a]	10,000	17,000	15,000

[a] Rounding may create inconsistencies in addition.

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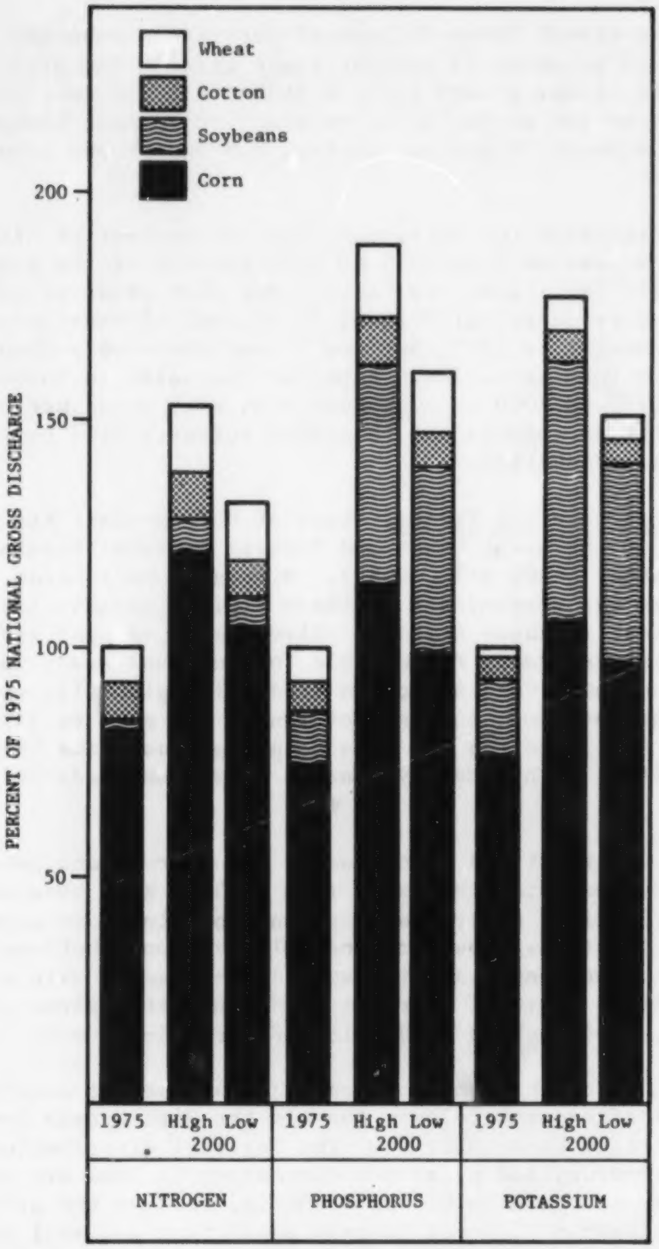
[108] U.S. Department of Agriculture, Soil Conservation Service, Environmental Impact Statement-Rural Clean Water Program, August 1978, p. 59.



NOTE: Crops contributing less than 0.5 percent are not shown. These 1975 National Gross Nutrient Discharges = 10,000 tons (5,700 tons of phosphorous, and 1,400 tons of potassium).

FIGURE 6-20
TRENDS IN GROSS DISCHARGES IN NUTRIENTS IN AGRICULTURAL RUNOFF, BY CROP 1975 AND 2000

In the Low Growth Scenario, annual nutrient discharges in 2000 are projected to be about 15 percent lower than in the High Growth Scenario due to slower growth in crop production and crop acreage. Nitrogen releases are projected to be about 30 percent higher than in 1975, potassium about 50 percent higher, and phosphorus about 60 percent higher.

Corn is projected to contribute about 80 percent of nitrogen loads in both scenarios from 1975 to 2000 because of the higher rates of soil loss and fertilizer application for corn relative to the other crops. Corn contributed about 75 percent of phosphorus and potassium discharges in 1975, but would contribute only about 60 percent by 2000 in both scenarios. Expected increases in soybean production from 1975 to 2000 in both scenarios will mean that a larger portion of total phosphorus and potassium releases will be attributable to soybean production.

Analysis of Nutrient Trends. Most of the nutrient discharges in 1975 occurred in the Great Lakes and Central Regions (Federal Regions V and VII) (Tables 6-30, 6-31, 6-32). Nitrogen, phosphorus, and potassium usage was predominant in these regions because corn production was heaviest in these regions. Elsewhere, corn and soybean production was also generally responsible for nutrient loads in 1975. However, in the South Central Region (Federal Region VI), where cotton is an important crop, cotton contributed the most to nitrogen loads (Figure 6-21); cotton and corn to phosphorus loads (Figure 6-22); and cotton, corn, and soybeans to potassium loads (Figure 6-23).

Regional distributions of nitrogen, phosphorus, and potassium releases are not expected to change from 1975 to 2000 because the regional distributions of crop acreage and soil loss are expected to remain fairly constant. However, the relative contributions of different crops to nutrient loads is expected to change, with soybeans producing a larger share of nutrient loads in most regions as a result of increased soybean production (Figures 6-21, 6-22, 6-23).

In the Low Growth Scenario, regional releases of nutrients are projected to increase more slowly than in the High Growth Scenario due to less acreage in production. The regional distributions of nitrogen, phosphorus, and potassium discharges by 2000 are necessarily the same as in the High Growth Scenario, because the projected regional distribution of acres in crop production and soil loss by 2000 are the same in both scenarios.

TABLE 6-30
TRENDS IN REGIONAL GROSS DISCHARGES OF NITROGEN IN AGRICULTURAL RUNOFF
HIGH GROWTH SCENARIO
1975 AND 2000

		1975		2000	
	Region	Quantity (Tons)[a]	Percent of National Total	Percent of 1975 Value	Percent of National Total
I	New England	b	b	b	b
II	New York-New Jersey	32	1	151	1
III	Middle Atlantic	350	6	151	6
IV	Southeast	840	15	153	15
V	Great Lakes	2,200	37	152	37
VI	South Central	560	10	148	9
VII	Central	1,600	28	154	28
VIII	Mountain	74	1	167	1
IX	West	32	1	150	1
X	Northwest	120	2	188	1
	Total[c]	5,700	100	153	100

---

[a] These discharges reflect commercial fertilizers only. For croplands included in these projections, they may be uniformly too low by a factor of four or five; see introduction to Section 6.3.3.

[b] No reported pollutants because cotton, corn, soybeans, and wheat are not projected for Region I.

[c] Rounding may create inconsistencies in addition.

TABLE 6-31
TRENDS IN REGIONAL GROSS DISCHARGES OF PHOSPHORUS IN AGRICULTURAL RUNOFF
HIGH GROWTH SCENARIO
1975 AND 2000

		1975		2000	
	Region	Quantity (Tons)[a]	Percent of National Total	Percent of 1975 Value	Percent of National Total
I	New England	b	b	b	b
II	New York-New Jersey	16	1	158	1
III	Middle Atlantic	170	6	169	5
IV	Southeast	480	16	207	17
V	Great Lakes	1,100	37	182	36
VI	South Central	280	9	197	10
VII	Central	850	28	185	28
VIII	Mountain	36	1	189	1
IX	West	14	c	181	c
X	Northwest	56	2	214	2
	Total[d]	3,000	100	188	100

[a] These discharges reflect commercial fertilizers use on corn, cotton, soybeans and wheat only, and may uniformly be too low by a factor of four or five; see introduction to Section 6.3.3.

[b] No reported pollutants because cotton, corn, soybeans, and wheat are not projected for Region I.

[c] Less than 0.5 percent.

[d] Rounding may create inconsistencies in addition.

TABLE 6-32
TRENDS IN REGIONAL GROSS DISCHARGES OF POTASSIUM IN AGRICULTURAL RUNOFF
HIGH GROWTH SCENARIO
1975 AND 2000

	Region	1975		2000	
		Quantity (Tons)[a]	Percent of National Total	Percent of 1975 Value	Percent of National Total
I	New England	b	b	b	b
II	New York-New Jersey	8	1	152	c
III	Middle Atlantic	83	6	155	5
IV	Southeast	240	16	200	19
V	Great Lakes	560	38	170	38
VI	South Central	120	8	192	9
VII	Central	410	29	174	28
VIII	Mountain	13	1	154	1
IX	West	5	c	158	c
X	Northwest	13	1	164	1
	Total[d]	1,400	100	177	100

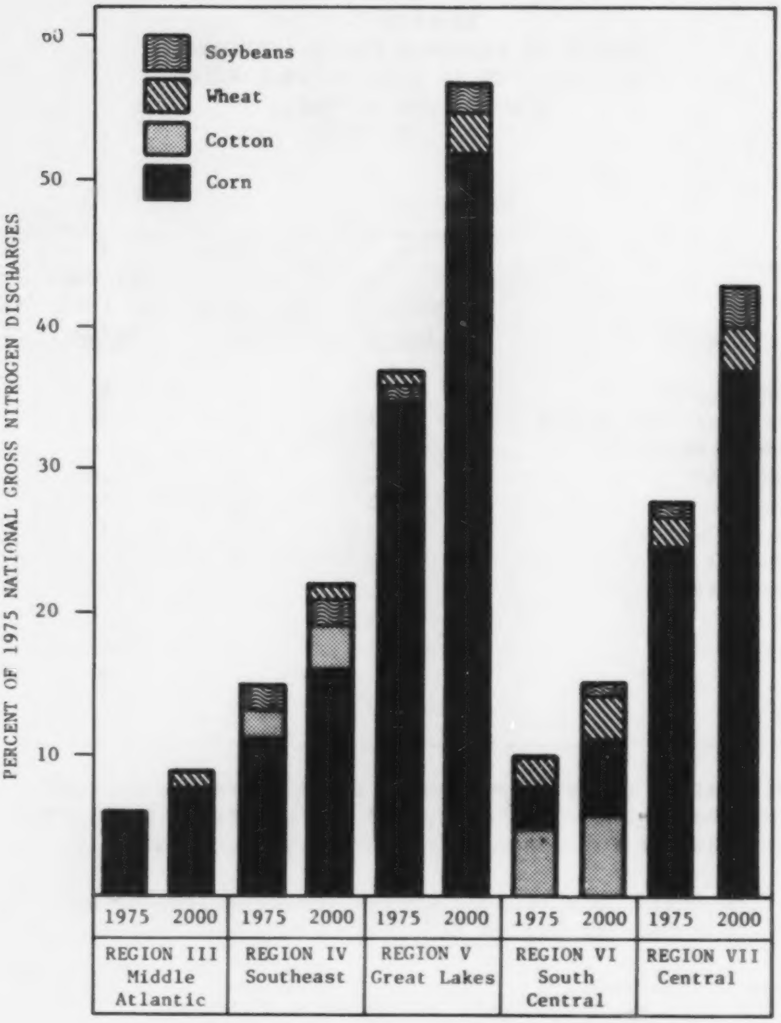
---

[a] These discharges reflect commercial fertilizers use on corn, cotton, soybeans and wheat only, and may uniformly be too low by a factor of four or five; see introduction to Section 6.3.3.

[b] No reported pollutants because cotton, corn, soybeans, and wheat are not projected for Region I.

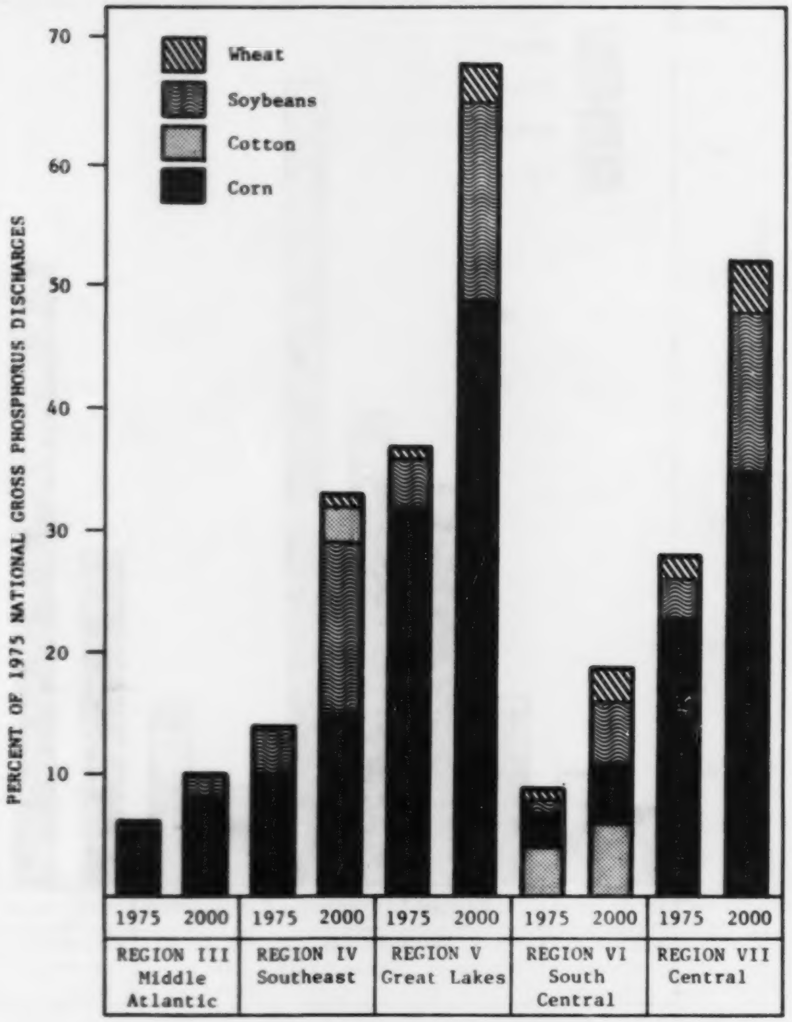
[c] Less than 0.5 percent.

[d] Rounding may create inconsistencies in addition.



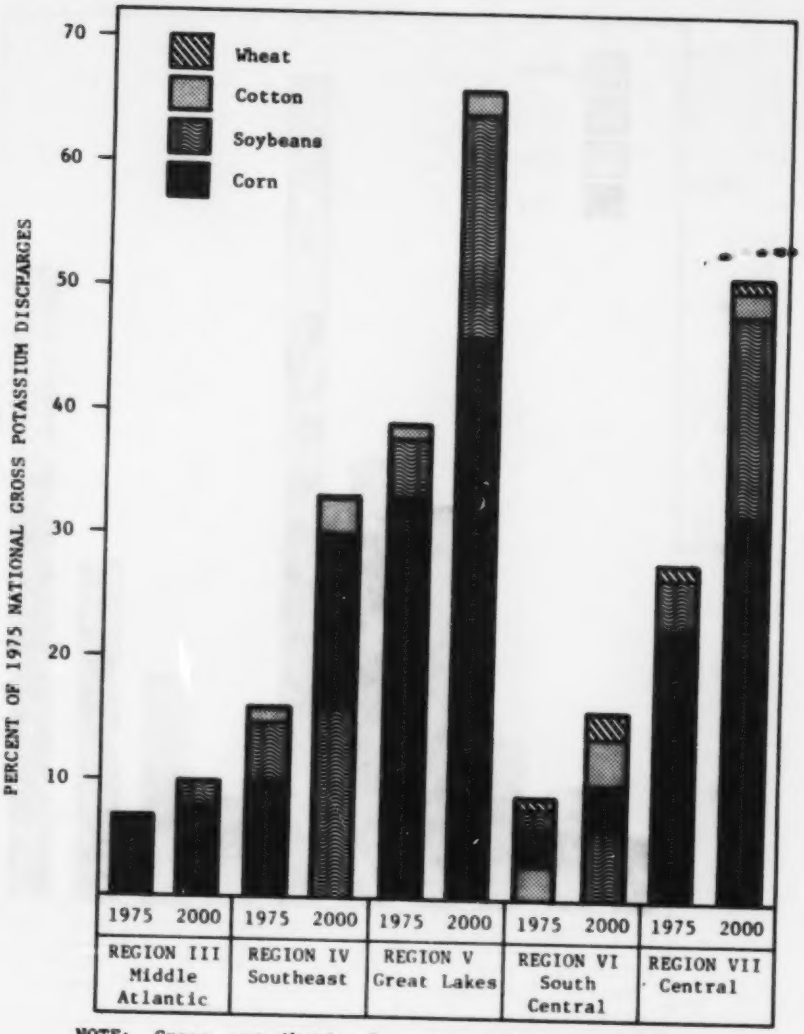
NOTE: Crops contributing less than 0.5 percent are not shown.
1975 National Gross Nitrogen Discharges = 5,700 tons.

FIGURE 6-21
TRENDS IN REGIONAL GROSS DISCHARGES OF NITROGEN
IN AGRICULTURAL RUNOFF, BY CROP
REGIONS III, IV, V, VI, AND VII
HIGH GROWTH SCENARIO
1975 AND 2000



NOTE: Crops contributing less than 0.5 percent are not shown.
1975 National Gross Phosphorus Discharges = 3,000 tons.

FIGURE 6-22
TRENDS IN REGIONAL GROSS DISCHARGES OF PHOSPHORUS
IN AGRICULTURAL RUNOFF, BY CROP
REGIONS III, IV, V, VI, AND VII
HIGH GROWTH SCENARIO
1975 AND 2000



NOTE: Crops contributing less than 0.5 percent are not shown. 1975 National Gross Potassium Discharges = 1,400 tons.

FIGURE 6-23
TRENDS IN REGIONAL GROSS DISCHARGES OF POTASSIUM IN AGRICULTURAL RUNOFF, BY CROP
REGIONS III, IV, V, VI, AND VII
HIGH GROWTH SCENARIO
1975 AND 2000

Pesticide Discharge Trends

General Trends. Gross discharges of pesticides (Figure 6-24 and Table 6-33) are significant because of their toxicity, but are smaller than discharges of the other pollutants.

Discharges of fungicides are expected to increase the most from 1975 to 2000, largely because of increased use per acre for potatoes and soybeans and higher soybean acreage. Potatoes and soybeans are projected to account for about 85 percent of fungicide loads by 2000.

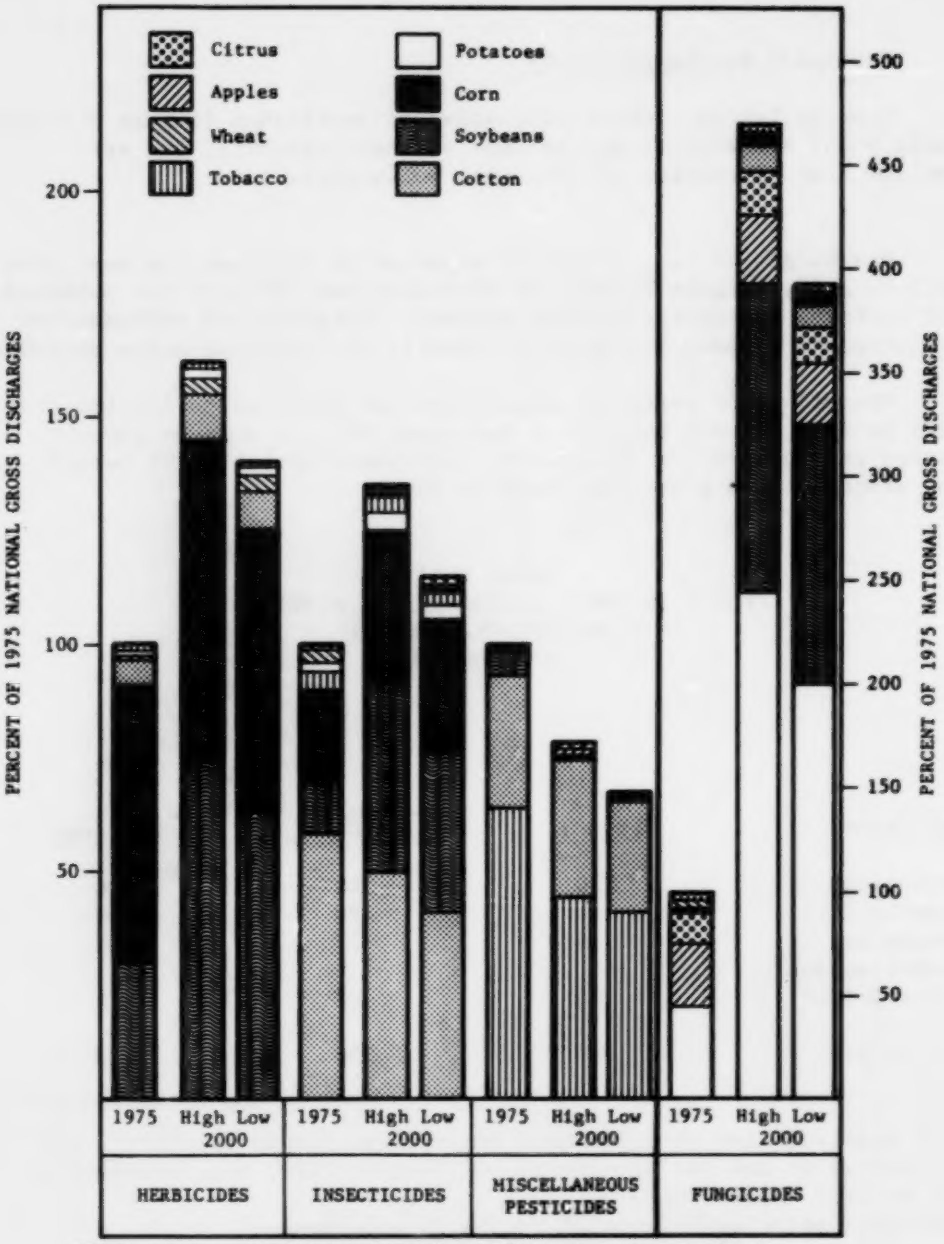
Miscellaneous pesticide discharges are expected to decline from 1975 to 2000, mainly because of decreased use per acre on tobacco. Cotton and tobacco are expected to contribute more than 95 percent of the miscellaneous pesticide loads by 2000.

TABLE 6-33
TRENDS IN GROSS DISCHARGES OF PESTICIDES IN AGRICULTURAL RUNOFF[a]
1975 AND 2000

Pollutant	1975 (tons)	2000 (tons) High Growth	2000 (tons) Low Growth
Herbicides	230	380	320
Insecticides	88	120	100
Fungicides	6	27	23
Miscellaneous Pesticides	35	27	24
Total[b]	360	550	470

[a] For croplands included in these projections, these discharges may uniformly be too low by a factor of four or five; see introduction to Section 6.3.3.

[b] Rounding may create inconsistencies in addition.



NOTE: Crops contributing less than 0.5 percent are not shown. 1975 National Gross Pesticide Discharge = 360 tons (230 tons of herbicides, 88 tons of insecticides, 6 tons of fungicides, and 35 tons of miscellaneous pesticides).

FIGURE 6-24
TRENDS IN GROSS DISCHARGES OF PESTICIDES IN AGRICULTURAL RUNOFF, BY CROP 1975 AND 2000

About 90 percent of herbicide releases by 2000 are expected to be related to corn and soybean production. Cotton, corn, and soybeans are projected to contribute the bulk to insecticide loads (about 90 percent by 2000).

In the Low Growth Scenario, similar trends are anticipated. Compared to High Growth, pollutant discharges are expected to be about 15 percent lower for each class of pesticides due to smaller increases (or larger decreases) in crop acreage.

Analysis of Pesticide Trends. Our projections of gross discharges of pesticides depend mainly on two factors: trends in pesticide application rates for the various crops studied, and regional trends in sediment losses incurred in growing each crop.

In 1975, the Great Lakes and Central Regions (Federal Regions V and VII) contributed most to herbicide discharges (Table 6-34), since

TABLE 6-34
TRENDS IN REGIONAL GROSS DISCHARGES OF HERBICIDES IN AGRICULTURAL RUNOFF
HIGH GROWTH SCENARIO
1975 AND 2000

		1975		2000	
	Region	Quantity (Tons)[a]	Percent of National Total	Percent of 1975 Value	Percent of National Total
I	New England	b	c	371	c
II	New York-New Jersey	1	c	143	c
III	Middle Atlantic	12	5	139	4
IV	Southeast	44	19	181	21
V	Great Lakes	83	36	154	34
VI	South Central	23	10	179	11
VII	Central	63	27	158	27
VIII	Mountain	2	1	150	1
IX	West	1	c	172	c
X	Northwest	2	1	266	2
	Total[d]	230	100	163	100

---

[a] For croplands included in these projections, these discharges may uniformly be too low by a factor of four or five. See introduction to Section 6.3.3.

[b] Less than 0.5 tons.

[c] Less than 0.5 percent.

[d] Rounding may create inconsistencies in addition.

herbicides are used extensively on corn and soybeans and most of the production of these crops was in these two regions. In the other regions as well, corn and soybeans were the major contributors to herbicide loads in 1975 (Figure 6-25).

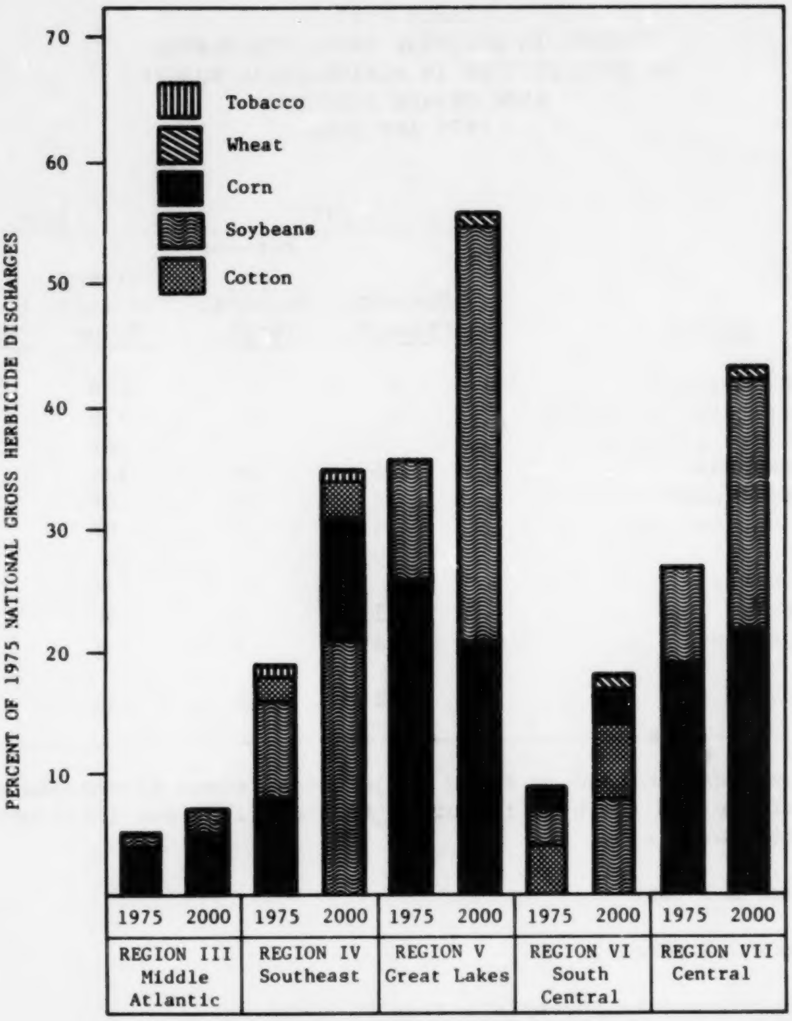
By 2000, Federal Regions V and VII would still have the highest herbicide releases in both scenarios. Although the New England Region (Federal Region I) would generate a very small fraction of total herbicide releases, the herbicide load would increase faster there than in any other region because of increases in potato acreage between 1975 and 2000.

In the Low Growth Scenario, herbicide discharges from 1975 to 2000 are projected to increase about 15 percent less than in the High Growth Scenario due to smaller increases in crop production, with the regional distribution of herbicide discharges in 2000 the same as in the High Growth Scenario.

The regional pattern of insecticide discharges varies over time. In 1975, about 65 percent of the insecticide releases occurred in the Southeast and South Central Regions (Federal Regions IV and VI), because insecticides are used heavily on cotton, and those two regions had about 80 percent of the cotton acreage in 1975 (Table 6-35). From 1975 to 2000, in the High Growth Scenario, insecticide use per acre is assumed to decline for cotton and increase for soybeans; soybean acreage in the Great Lakes and Central Regions (Federal Regions V and VII) is expected to increase and cotton acreage in the South Central Region (Federal Region VI) is expected to decline. As a result, insecticide releases are expected to decline in Federal Region VI and double in Federal Regions V and VII. Consequently, both the regional distribution of insecticide discharges and the relative contribution by different crops to insecticide loads are projected to shift by 2000 (Figure 6-26).

In the Low Growth Scenario, the increase in insecticide discharges is expected to be about 15 percent lower because of smaller increases in crop production, with the regional distribution of insecticide discharges the same for both scenarios throughout the 1975 to 2000 period.

Because of the amount of potato production, the Northwest Region (Federal Region X) accounted for about 40 percent of the total fungicide discharges in 1975 (Table 6-36). Fungicide application rates are projected to increase for both potatoes and soybeans. Since soybean acreage is expected to increase in the Great Lakes and Central Regions (Federal Regions V and VII), the regional distribution of fungicide discharges would shift by 2000. While Federal Region X still would contribute more than one-third of the total, Federal



NOTE: Crops contributing less than 0.5 percent are not shown.
1975 National Gross Herbicide Discharges = 230 tons.

FIGURE 6-25
TRENDS IN REGIONAL DISCHARGES OF HERBICIDES
IN AGRICULTURAL RUNOFF, BY CROP
REGIONS III, IV, V, VI, AND VII
HIGH GROWTH SCENARIO
1975 AND 2000

TABLE 6-35
TRENDS IN REGIONAL GROSS DISCHARGES OF INSECTICIDES IN AGRICULTURAL RUNOFF
HIGH GROWTH SCENARIO
1975 AND 2000

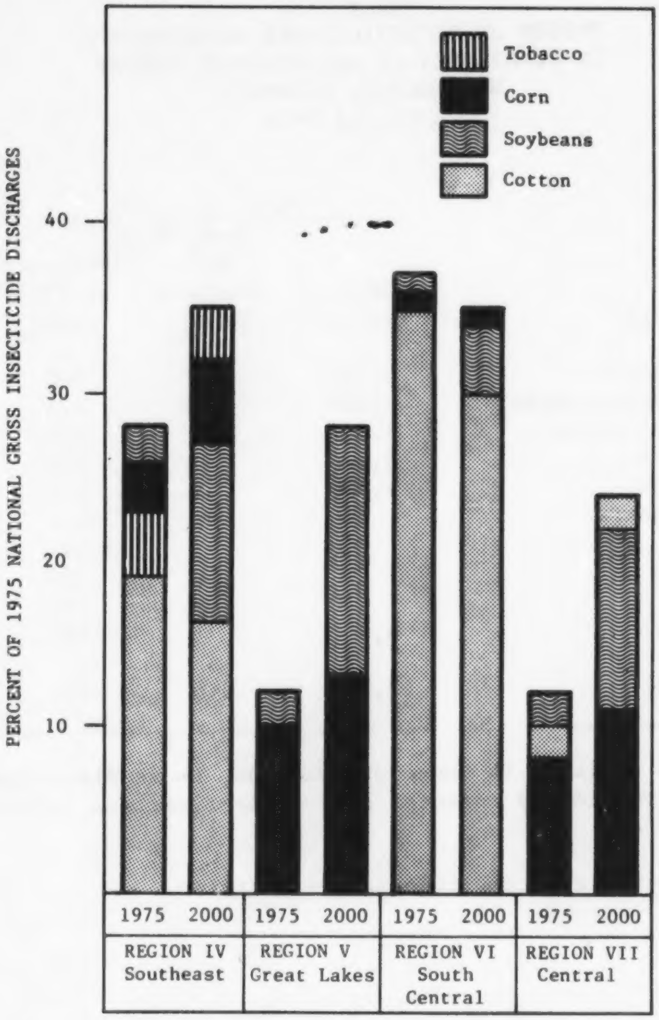
		1975		2000	
	Region	Quantity (Tons)[a]	Percent of National Total	Percent of 1975 Value	Percent of National Total
I	New England	b	c	138	c
II	New York-New Jersey	b	c	139	c
III	Middle Atlantic	3	3	141	3
IV	Southeast	25	28	124	26
V	Great Lakes	12	14	209	21
VI	South Central	33	37	97	27
VII	Central	10	12	196	18
VIII	Mountain	b	c	134	c
IX	West	2	2	90	2
X	Northwest	2	2	142	2
	Total[d]	88	100	134	100

[a] For croplands included in these projections, these discharges may uniformly be too low by a factor of four or five; see introduction to Section 6.3.3.

[b] Less than 0.5 ton.

[c] Less than 0.5 percent.

[d] Rounding may create inconsistencies in addition.



NOTE: Crops contributing less than 0.5 percent are not shown.
1975 National Gross Insecticide Discharges = 88 tons.

FIGURE 6-26
TRENDS IN REGIONAL GROSS DISCHARGES OF INSECTICIDES
IN AGRICULTURAL RUNOFF, BY CROP
REGIONS IV, V, VI, AND VII
HIGH GROWTH SCENARIO
1975 AND 2000

TABLE 6-36
TRENDS IN REGIONAL GROSS DISCHARGES OF FUNGICIDES IN AGRICULTURAL RUNOFF
HIGH GROWTH SCENARIO
1975 AND 2000

	Region	1975		2000	
		Quantity (Pounds)[a]	Percent of National Total	Percent of 1975 Value	Percent of National Total
I	New England	400	3	380	3
II	New York-New Jersey	400	3	274	2
III	Middle Atlantic	1,600	14	224	7
IV	Southeast	2,200	20	403	17
V	Great Lakes	1,000	8	894	16
VI	South Central	400	3	896	6
VII	Central	200	2	2,010	10
VIII	Mountain	200	2	403	1
IX	West	400	4	251	2
X	Northwest	4,600	40	425	37
	Total[b]	12,000	100	469	100

[a] For croplands included in these projections, these discharges may uniformly be too low by a factor of four or five; see introduction to Section 6.3.3.

[b] Rounding may create inconsistencies in addition.

Regions V and VII would contribute about one-fourth of the fungicide loads by 2000 largely because of soybean production (Figure 6-27). Fungicide discharges are expected to grow most rapidly in Region VII in the High Growth Scenario, due to an expected increase of 60 percent in soybean acreage from 1975 to 2000.

In the Low Growth Scenario, fungicide discharges by 2000 are expected to be about 85 percent of their High Growth values due to smaller projected increases in crop production, with the regional distribution of discharges by 2000 the same as in the High Growth Scenario.

In general, regional discharges of miscellaneous pesticides are expected to decline from 1975 to 2000 due to assumed reductions in application rates (Table 6-37). In 1975, approximately two-thirds of

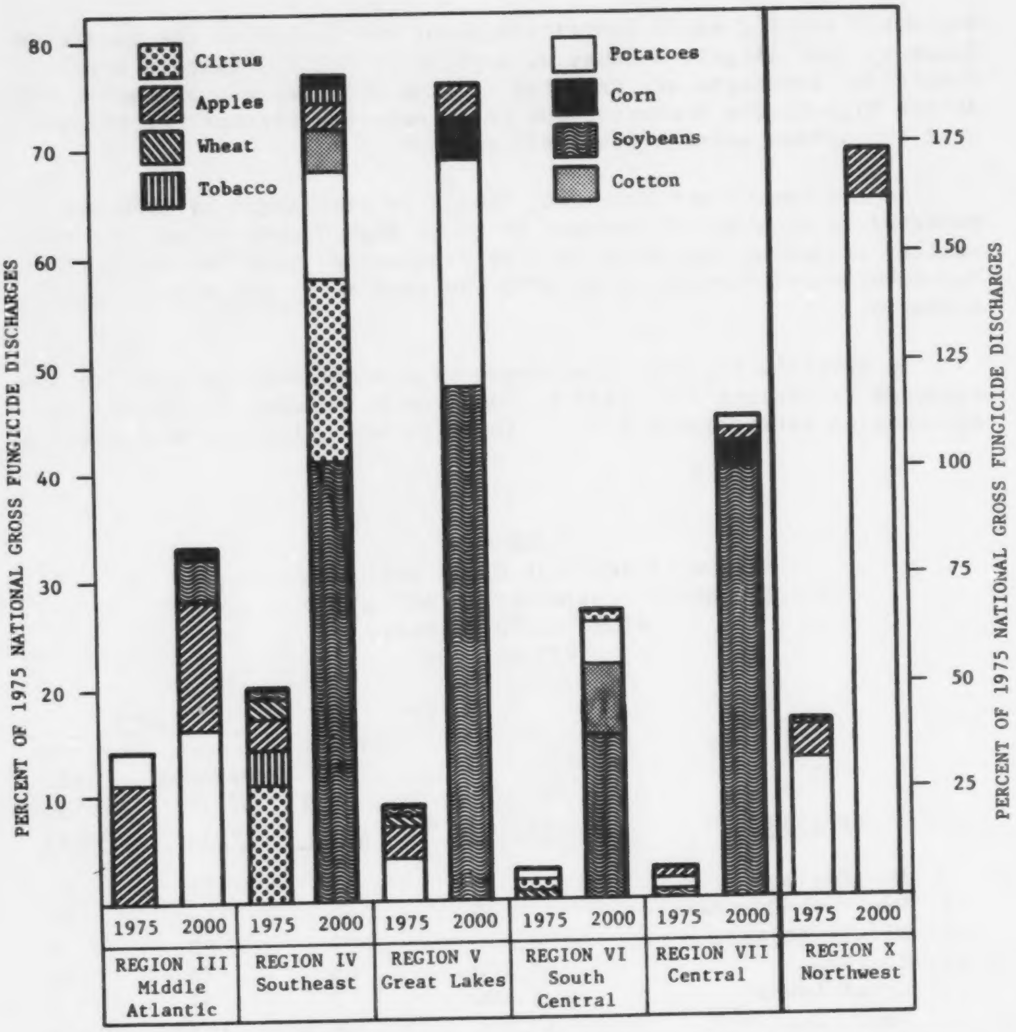
TABLE 6-37
TRENDS IN REGIONAL GROSS DISCHARGES OF
MISCELLANEOUS PESTICIDES IN AGRICULTURAL RUNOFF
HIGH GROWTH SCENARIO
1975 AND 2000

	Region	1975		2000	
		Quantity (Pounds)[a]	Percent of National Total	Percent of 1975 Value	Percent of National Total
I	New England	80	b	78	b
II	New York-New Jersey	30	b	114	b
III	Middle Atlantic	4,600	7	69	6
IV	Southeast	47,000	68	72	64
V	Great Lakes	2,100	3	37	1
VI	South Central	13,000	18	103	24
VII	Central	2,000	3	53	2
VIII	Mountain	10	b	57	b
IX	West	800	1	110	2
X	Northwest	70	b	150	b
	Total[c]	70,000	100	77	100

[a] For croplands included in these projections, these discharges may uniformly be too low by a factor of four or five; see introduction to Section 6.3.3.

[b] Less than 0.5 percent.

[c] Rounding may create inconsistencies in addition.



NOTE: Crops contributing less than 0.5 percent are not shown. 1975 National Gross Fungicide Discharges = 6 tons.

FIGURE 6-27
TRENDS IN REGIONAL GROSS DISCHARGES OF FUNGICIDES IN AGRICULTURAL RUNOFF, BY CROP
REGIONS III, IV, V, VI, VII, AND X
HIGH GROWTH SCENARIO
1975 AND 2000

the miscellaneous pesticide discharges occurred in the Southeast Region (Federal Region IV), because of heavy tobacco production (Figure 6-28). Miscellaneous pesticide use per acre is projected to decline for all crops except cotton and apples, which are assumed to remain constant. Since about 60 percent of the total cotton acreage is expected to be located in the South Central Region (Federal Region VI) from 1975 to 2000, the proportion of national total miscellaneous pesticide discharges in Federal Region VI is projected to increase somewhat by 2000. The proportion of discharges contributed by other regions would not change significantly.

In the Low Growth Scenario, miscellaneous pesticide discharges would be 15 percent less than in the High Growth Scenario by 2000, with the regional distribution of discharges by 2000 the same as in the High Growth Scenario.

6.3.4 Other Non-point Sources

HIGHLIGHTS OF SECTION 6.3.4

- Both mining and construction activities have localized water pollution impacts. These activities and their impacts are expected to increase from 1975 to 2000.
- Silvicultural activities have caused localized pollution but are not expected to have significant long-term impacts, especially when compared to other non-point sources.

Mining

Many studies have documented the water pollution aspects of mining and mine drainage.[109] Mine drainage includes water flowing from surface or underground mines by gravity or pumping, and runoff or seepage from mine lands or mine wastes. This drainage, carrying dissolved, suspended, or other mineral wastes and debris enters receiving streams or the groundwater system. This pollution may be physical (sediments) or chemical (acid) and much of it is harmful to aquatic or other life. Moreover, mine drainage may persist long after completion of mining, unless control measures are taken.[110]

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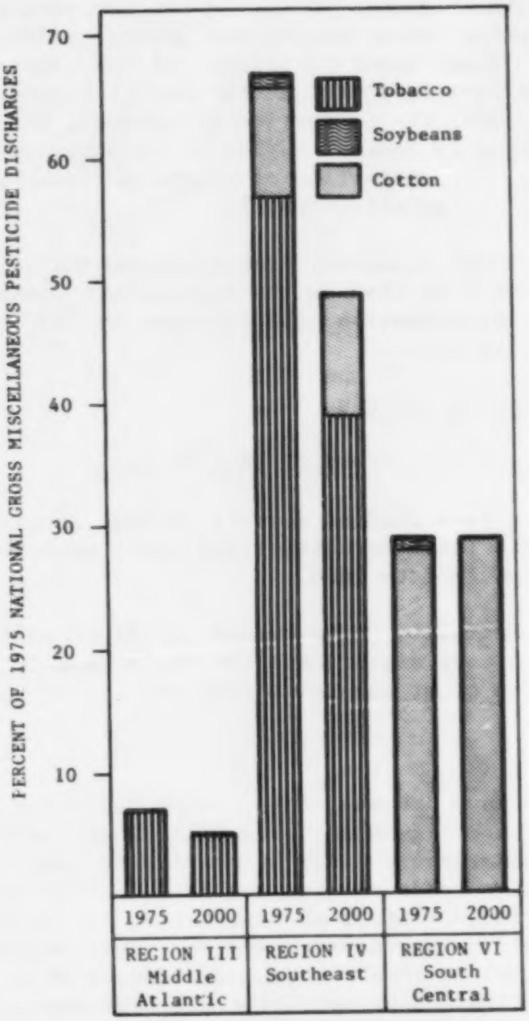
[109] U.S. Environmental Protection Agency, Methods for Identifying and Evaluation of the Nature and Extent of Nonpoint Source of Pollutants, EPA 430/9-73-014, October 1973, Chapter 5.0.

[110] U.S. Environmental Protection Agency, Processes, Procedures and Methods to Control Pollution from Mining Activities, EPA 430/9-73-011, October 1973, p. 1.



NOTE: Crops contributing less than 0.5 percent are not shown.
1975 National Gross Miscellaneous Pesticide Discharges = 35 tons.

FIGURE 6-28
TRENDS IN REGIONAL GROSS DISCHARGES OF MISCELLANEOUS PESTICIDES IN AGRICULTURAL RUNOFF, BY CROP
REGIONS III, IV, AND VI
1975 AND 2000

Over the past 150 years, mining activity has constantly increased in magnitude. Pollution problems reflect the range of substances mined--organic materials (coal, lignite, peat), gems, metal ores, and other metallic and nonmetallic minerals (talc, gypsum, limestone, dolomite, sandstone, sand, nitrate, phosphate, and others). The Bureau of Mines has estimated that, from 1930 through 1977, about 5 million acres of land have been mined, with about 2.3 million acres being for coal production. About 40 percent of all land utilized for mining has been reclaimed to some degree, with 1.5 million acres representing land reclaimed from coal production.[111]

Surface mining in its several forms--strip, open pit, dredging, and hydraulic--creates more visible defacement of the earth's surface than does underground mining. In strip mining, a large amount of overlying material is removed to expose an underlying deposit for extraction. Open pit mining, a common method for mining stone and copper, is similar to strip mining, except that little waste overburden is generated, since most of the material removed is valuable ore. Dredging is used to recover minerals from underwater; the mining of gravel accounts for most dredging production, but dredging has also been widely used in gold mining. Hydraulic mining is performed by directing a jet of high-velocity water at an unconsolidated deposit and is used almost exclusively for gold recovery.

Mining activity can be either a point source or a non-point source of water pollution and the classification is sometimes difficult. Control of water pollutants from certain parts of the mining site--notably disturbed land areas and refuse piles--is currently under state jurisdiction, and varies from state to state. Point source pollutant discharges are specifically controlled by National Pollutant Discharge Elimination System (NPDES) permits.

A mine-related non-point source can be defined as a contributing source resulting from mineral industry activity that causes surface water and/or groundwater pollution beyond those discharges controlled by NPDES permits. They include all pollutants from active, inactive, and abandoned surface and underground mine sites, as well as pollutants generated by mine spoils, mine haul roads, mineral exploration operations, mineral transport systems, mineral processing, storage, waste disposal, and other sources.[112]

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[111] Personal communication, P. Marcus and J. Peone, Division of Environment, Bureau of Mines, June 1979.

[112] Deely, D., Water Quality Management Guidance for Mine Related Pollution Sources, EPA Technical Guidance Memorandum, Tech 42, December 1977, pp. 1-2, 1-3.

The major piece of Federal legislation designed to control nonpoint discharges from mining activity is the Surface Mining Control and Reclamation Act of 1977 (PL 95-87). This act pertains to coal mining in particular and calls for a regulatory program to be promulgated in two stages. Interim final regulations were issued by the Department of Interior in accordance with Section 501(a) of the Act.[113] Section 501(b) required that permanent final regulations be published by August 3, 1978. These permanent regulations were delayed and were promulgated in final form on October 25, 1978 for the abandoned mine land reclamation program[114] and on March 13, 1979 for the permanent regulatory program.[115] Mine operators operate under existing interim final regulations until state programs have been approved or until a Federal program has been installed in accordance with the permanent regulations. The deadline for full compliance with the permanent regulations is February 3, 1981.

The interim final regulations established procedures (Best Management Practices) for nine of the 25 environmental protection performance standards specified in the Act, which cover all aspects of mining and reclamation. The permanent regulations cover all 25 areas.

All lands disturbed after the Surface Mining Control and Reclamation Act was passed must be reclaimed in accordance with regulations under the Act. Coal operators have four years in the East and nine years in the West to restore newly-disturbed land to an acceptable condition. In addition, the Act provides a program for restoring abandoned mine lands. In the future, mining discharges will be considered as point sources and regulated accordingly.

The most serious pollutant arising from mining is the acid mine drainage generated by oxidation of pyritic materials in water. This drainage is a mixture of iron salts, other salts, and sulfuric acid, and arises from both underground and surface mining sources, from coal and many metal mining operations. The acid can react with clay minerals to produce aluminum concentrations sufficient to kill fish, and with limestone to produce hard water. The acid can also extract heavy metals, present in trace quantities in mineral and soil formations, which can result in toxic conditions.

Acid mine drainage is generally associated with coal mining in Appalachia, although it is not found at all coal mines. It is also a problem in some hard rock (copper, silver, gold, etc.) mining areas in the western United States. The volume and composition of the mine drainage depends greatly upon local conditions; its environmental significance is equally specific to each situation.

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[113] Federal Register, Volume 42, p. 62639, December 13, 1977.
[114] Federal Register, Volume 43, p. 49932, October 25, 1978.
[115] Federal Register, Volume 44, p. 14902, March 13, 1979.

Mine drainage in Appalachia--in the Middle Atlantic and Southeast Regions (Federal Regions III and IV)--is best understood. The Appalachian Regional Commission estimated that 2.3 million tons of acids were discharged during 1966 from active and inactive surface mines and spoil piles in Appalachia.[116] A more recent (1975) estimate by Midwest Research Institute[117] indicated that about 2.9 million tons of acids are discharged elsewhere in the country, primarily from metal mining in the Mountain and West Regions (Federal Regions VIII and IX) and, in much smaller amounts, from coal mining in the South Central and Central Regions (Federal Regions VI and VII).

Whatever the exact size of the problem and how it may change in the future is uncertain. The effectiveness and lifetime of present methods of mine sealing vary according to method and environmental conditions. Further, the major source of acid mine drainage is from abandoned underground mines in Appalachia. Cost-effective methods for controlling such abandoned acid drainage sources have not yet been developed. Current methods of underground mining are essentially the same as in the past and consequently will produce the same sources of largely uncontrollable acid mine drainage. It has been estimated that only 25 percent of the acid mine drainage cases from now to the year 2000 will be controllable by using current technologies.[118]

Surface mining operations disturb large areas of land and leave them susceptible to erosion. This can contribute large quantities of sediment to surface waters if the land is not properly reclaimed after mining or if proper techniques for sediment control are not used. Sediment problems already arise from the many acres of land disturbed by past mining activity and not yet reclaimed.

Processing raw minerals to concentrate the ore creates vast piles of tailings, which can also produce sediment problems. This is especially prevalent in the western United States, where tailings from hard rock minerals processing have been spread over large areas.

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[116] Appalachian Regional Commission, Acid Mine Drainage in Appalachia, 1969.

[117] Midwest Research Institute, National Assessment of Water Pollution from Nonpoint Sources, Draft of Final Report, prepared for U.S. Environmental Protection Agency, Contract Number 6801-2293, November 1975, p. 27.

[118] Personal communication, Ronald Hill, U.S. Environmental Protection Agency, Resource Extraction and Handling Division, Industrial Environmental Research Laboratory, Cincinnati, Ohio, January 1979.

The nature and extent of the sediment problem depends on the location of the mining operation, the type of mining, and the degree of reclamation. In mountainous coal-mining areas, reclamation and sediment control problems are especially difficult. Contour mining of coal is the largest single source of sediment from mining operations. Contour mining involves dumping the overburden or spoil on the downslope side of the cut in order to expose the coal seam, and leaves a "highwall", the steep cliff remaining above the cut after coal has been removed. Such a site is highly susceptible to erosion. The Surface Mining Control and Reclamation Act will require restoration of all new mines to the original land contours.

Estimates of soil loss per acre from active surface mining operations are 10 times that from cropland and equal to that from construction.[119] Estimates of the sediment loss from mining have ranged from 20 million tons[120] to 60 million tons[121] per year, but little information is available on which to base estimates. A few studies of sediment loadings in major river basins have been conducted, but these are an exception.[122]

Mining can create a significant problem in areas where ground water is a source of water supply. For example, blasting can fracture local rock strata, providing entries for mine drainage or saline water to aquifers. Generally, groundwater pollution from mining operations can be controlled by sealing the bottoms of polluted water containments.

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[119] See Table 6-23.

[120] Brant, Gerald H. et al. An Economic Analysis of Erosion and Sediment Control Methods for Watersheds Undergoing Urbanization. PB-209 212. Midland, Michigan: Dow Chemical Company, February 1972.

[121] Midwest Research Institute, National Assessment of Water Pollution from Nonpoint Sources, Draft of Final Report, prepared for U.S. Environmental Protection Agency, Contract Number 68-01-2293, November 1975, p. 16.

[122] Experts from EPA's Office of Water Planning and Standards, Nonpoint Source Branch; EPA's Office of Research and Development, Agricultural and Nonpoint Management Division; Department of Interior's Bureau of Mines, Office of Surface Mining Reclamation and Enforcement; Department of Agriculture's Soil Conservation Service, Land Use Data and Erosion Sedimentation Division; and the Appalachian Regional Commission, are not aware of any other reports containing national estimates of sediment loss due to coal mining or other mining activities.

Leachate, the discharge of polluted water arising from water percolation in waste rock piles, is another source of pollution in coal mining regions where coal refuse and mine spoil are exposed to weathering, and in the western United States, where tailings piles and mining operations subject to leaching are located on fractured rock. Control of leachate pollution from tailings piles is often hampered by mining company effort to save the tailings for future mineral extraction. Some tailings piles have existed 50 years or more without adequate maintenance; piles have been eroded by water and wind, and seals between ponds and bedrock have deteriorated.

Radioactivity arising from mining activities is of especial concern in the western United States, where uranium ore mining and processing may release uranium and radium from mill tailings.

Finally, during the mining reclamation process nutrient and pesticide pollution can become a problem if techniques and timing of applications are improper.

Currently, about 30 percent of the EPA-designated hydrological drainage basins in the United States are affected by runoff or drainage from active or abandoned mines (Figure 6-29). In most areas, the most severe control problems are due to abandoned mines and unreclaimed land from past mining activities, since generally mining today is better regulated and more mine land is reclaimed.

The extent and type of pollution problems vary considerably with geographic region. In the Great Lakes Region (Federal Region V), about 40 percent of the basins are affected by mining activities (largely coal mining), and sediment is a particular problem. Moreover, acidity from non-point sources affects almost 40 percent of the basins, which is more than double the percentage for the rest of the country. In the South Central, Central, Mountain, and West Regions (Federal Regions VI, VII, VIII, and IX)--which have considerable ore mining activity--about 40 to 50 percent of the water basins are affected. Heavy metals are the principal problem. In contrast, in the Southeast Region (Federal Region IV) only 15 percent of basins are affected by mining activities.[123]

From 1975 to 2000, mining activity is expected to show a sizable increase (Table 6-38). Despite regulation of some current and future mining operations, the increased activity will still cause adverse

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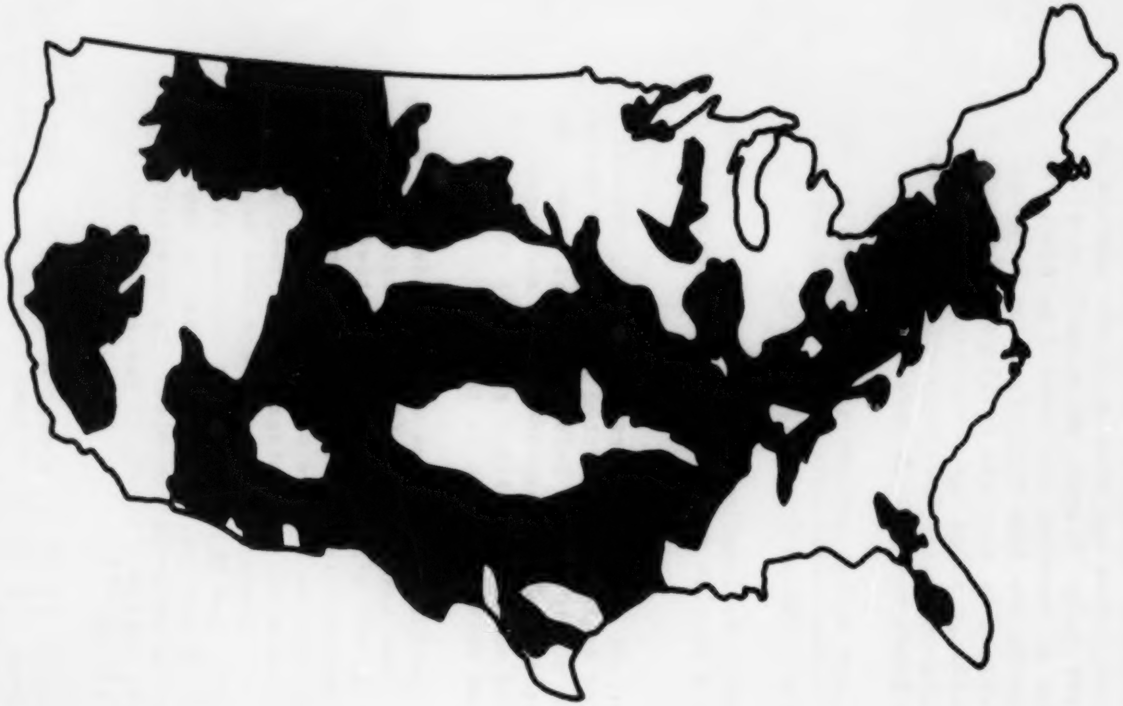
[123] U.S. Environmental Protection Agency, National Water Quality/ 1977 Report to Congress, EPA 440/4-78-001, October 1978, pp. 18, 22.



NOTE: Basins where some (or all) stream segments have a problem with pollution from mining activities that is not minor or insignificant, according to state officials. Affected basins are shaded.

Source: U.S. Environmental Protection Agency, National Water Quality Inventory/ 1977 Report to Congress, EPA 440/4-78-001, Washington, D.C., October 1978, p. 21.

FIGURE 6-29
EPA-DESIGNATED HYDROLOGICAL DRAINAGE BASINS AFFECTED BY POLLUTION FROM MINING ACTIVITIES
1977

TABLE 6-38
TRENDS IN THE OUTPUT OF THE MINING INDUSTRY
1975 AND 2000
(MILLIONS OF 1971 DOLLARS)

		High Growth		Low Growth		Scenario Difference[a] (Percent)
	1975	2000	Percent of 1975 Value	2000	Percent of 1975 Value	
Iron Ores	1,700	2,890	170	2,700	159	- 7
Copper Ores	1,330	2,840	214	2,470	186	-13
Coal	5,380	15,200	283	10,900	203	-28
Other Non-Ferrous Ores (Uranium)	920	2,660	289	2,330	253	-16
Stone and Clay	2,780	7,470	269	7,170	258	- 4
Chemicals and Fertilizers (sulfur and phosphate)	850	2,220	261	1,920	226	-13

[a] (Low Growth - High Growth) ÷ High Growth.

impacts on water quality, at least in the short term while active mining is occurring and before reclamation is complete. Thus, concern for water quality as a result of mining activity will be an important issue during the 1975 to 2000 period and beyond.

Silviculture[124]

About 500 million acres of land in the United States are classified as commercial timberland. Depending upon natural characteristics and management, these lands can be minor or major sources of surface water pollution.

An established, well-managed forest can be remarkably resistant to emitting pollutants. Tree cover deprives rainfall of most of its erosive force; intense rainfall can often be accommodated without runoff and erosion.

Natural events--windstorms, droughts, fires, disease, insects--can devastate a forest and promote heavy erosion and stream pollution. Silvicultural activities, which are generally concerned with growing and harvesting timber, preventing natural devastation, and restoring productivity, can also result in pollution. These activities include logging, timber stand improvement, the building and use of logging roads, prescribed and slash burnings, and fertilization and pesticide application.

Logging road construction, maintenance, and use and mechanized forest operations probably have the most significant environmental impacts. Increased erosion accompanies logging road construction, and, especially with poor design, stream sediment loads can greatly increase. Mechanized operations can compact the soil and decrease soil productivity, destroy wildlife habitat, and leave the soil exposed to erosion. Recovery from soil compaction can take 3 to 10 years.

Pesticides and fertilizers are applied to forest lands only in rather special circumstances. In 1972, only 0.002 percent of commercial forest lands received insecticide applications. Only about

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[124] Much of the description of this section is based on: U.S. Environmental Protection Agency, Methods for Identifying and Evaluating the Nature and Extent of Nonpoint Sources of Pollutants, EPA 430/9-73-014, October 1973, Chapter 4.; and Development Planning and Research Associates, Inc., Environmental Implications of Trends in Agriculture and Silviculture - Volume I: Trend Identification and Evaluation, EPA 600/3-77-121, October 1977, Chapter X.

500,000 acres receive fertilizer applications in one year. Consequently, nutrient discharges from fertilizing forests are minor compared to those from agricultural activities.

The most important pollutant originating from silvicultural activities is sediment. On a per acre basis, sediment loss from recently logged forestland is estimated to be about 2.5 times that from cropland.[125] On a total mass basis, estimates of sediment loss per year from silvicultural activities range from 140 million tons[126] to 263 million tons,[127] far less than that from all croplands.

Vegetative and animal organic matter transported to surface waters by runoff ranges from green vegetative refuse through well-decomposed humic matter. It is sometimes a nuisance (floating debris); sometimes physically damages aquatic habitat (bark deposited in spawning beds); and nearly always exerts a biochemical oxygen demand. BOD discharges from silvicultural activities have been estimated at about 8 million tons per year.[128]

Insecticides, fungicides, herbicides, and rodenticides used to protect forests may be deposited directly in surface water sources by careless application, or be transported in surface runoff. Pesticides differ from other forest pollutants in that they are, by design, toxic to some part of the forest ecosystem. Their pollution potential depends on their persistence, rates, and modes of degradation, mechanisms by which they may be transported to nontarget species, and their toxicity to nontarget species. The continuing controversy over the effects on human beings as well as wildlife of the past use of the herbicide 2,4,5-T on forests is one example of the unforeseen problems that can arise from the widespread use of pesticides.

Fertilizers and fire retardants also may pollute streams and lakes by releasing nutrient compounds, mainly nitrogen and phosphorus. Nitrogen, phosphorus, and other mineral nutrients can also be added to streams where the cutting or burning of forests interrupts the natural nutrient cycling of the forest ecosystem. Nitrogen, water soluble in both the ammonia and nitrate forms, is much more susceptible to transport in runoff and infiltrating water than is phosphorus. Ammonia is toxic to fish at the part-per-million concentration range, and the nitrate ion is toxic under certain conditions. Phosphorus is noted chiefly because it accelerates eutrophication processes. Both nitrogen and phosphorus are highly essential elements, present naturally in abundance; they become pollutants when their presence adversely affects the aquatic ecosystems. Silvicultural activities have been estimated to release 400,000 tons of nitrogen and 100,000 tons of phosphorus per year to surface waters.[129]

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[125] See Table 6-25.

[126] Dow Chemical Company, An Economic Analysis of Erosion and Sediment Control Methods for Watersheds Undergoing Urbanization, February 1972, p. 15.

[127] Midwest Research Institute, National Assessment of Water Pollution From Nonpoint Sources, Draft of Final Report, prepared for U.S. Environmental Protection Agency, Contract Number 68-01-2293, November 1974, p. 16.

[128] Ibid.

Bacterial pollution of surface waters from forestlands can originate from soils, plant, and tree debris, and most importantly, from animal and human wastes. Pathogenic agents from these sources may infect animals or, in some cases, human beings.

Finally, thermal pollution from solar radiation can result from silvicultural activities. Removal of tree cover may result in a substantial increase in stream water temperatures, with detrimental impact on fish and fish spawning.

About 15 percent of all EPA-designated hydrological drainage basins in the United States are affected by silvicultural activities (Figure 6-30).[130] The West and Northwest Regions (Federal Regions IX and X) have the largest proportion of affected basins--almost 30 percent.

Preliminary data[131] indicate that 204 million acres of ungrazed forestland and 42 million acres of grazed forestland, privately owned, need some type of conservation treatment--two-thirds of all non-federal forestland. Some of the identified needs are: 1 million acres of planting and seeding; 11,000 miles of road stabilization; and 5.4 million acres of stand improvement.[132] These needs bear

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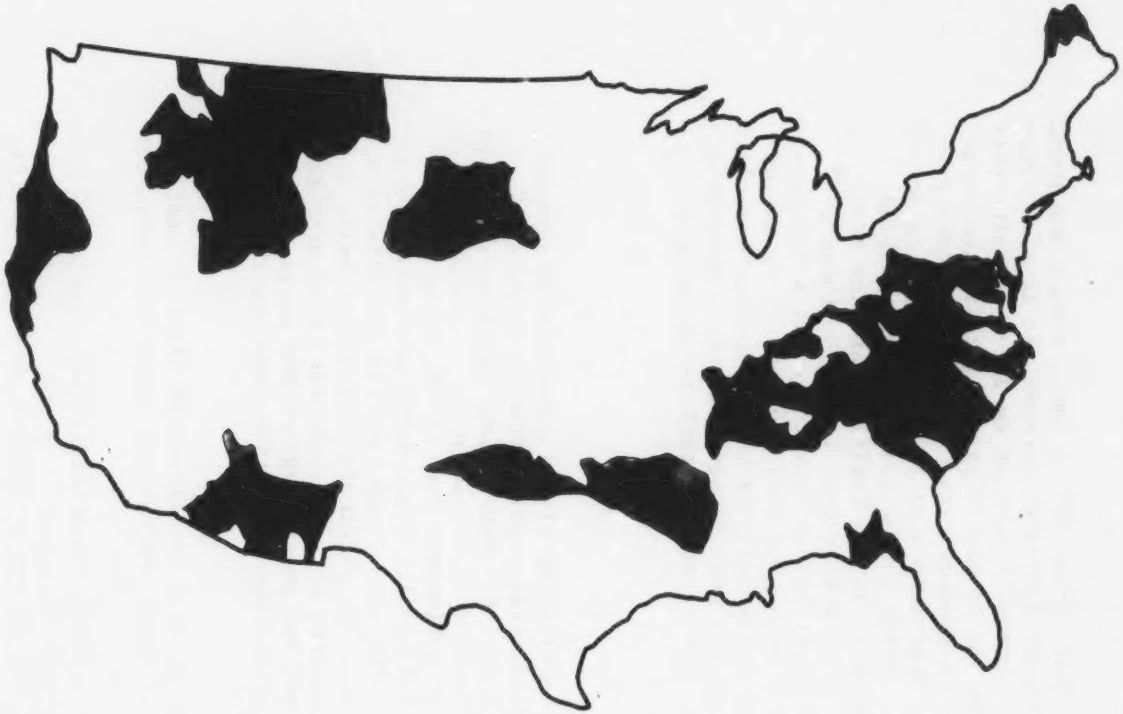
[129] Midwest Research Institute, National Assessment of Water Pollution From Nonpoint Sources, Draft of Final Report, prepared for U.S. Environmental Protection Agency, Contract Number 68-01-2293, November 1974, p. 16.

[130] U.S. Environmental Protection Agency, National Water Quality Inventory/1977 Report to Congress, EPA 440/4-78-001, October 1978, p. 16.

[131] U.S. Department of Agriculture, Soil Conservation Service, National Resource Inventories - 1977, December 1978 (unpublished data).

[132] U.S. Department of Agriculture, Soil Conservation Service, Environmental Impact Statement - Rural Clean Water Program, August 1978, p.26.



NOTE: Basins where some (or all) stream segments have a problem with pollution from silvicultural activities that is not minor or insignificant, according to state officials. Affected basins are shaded.

Source: U.S. Environmental Protection Agency, National Water Quality Inventory/1977 Report to Congress, EPA 440/4-78-001, Washington, D.C., October 1978, p. 20.

FIGURE 6-30
EPA-DESIGNATED HYDROLOGICAL DRAINAGE BASINS AFFECTED BY POLLUTION FROM SILVICULTURAL ACTIVITIES
1977

directly or indirectly on the water pollution yield of U.S. forestlands.

It has been estimated that, from 1975 to 2000, demand for roundwood and sawtimber products will increase; however, it is also estimated that forestland will decrease 5 percent by 2010. Despite this reduction, increased demands can be met if proper forest management practices are used to increase productivity. It has also been projected that Best Management Practices will be applied more extensively in the future, most notably in the form of improved road construction and road maintenance in the Pacific Coast and Rocky Mountain areas and improved site preparation in the Southeast.[133] Although pesticide and fertilizer use is expected to be a little more extensive by 2010, no greater effect on this environment is anticipated. In sum, the water pollution effects of silvicultural activities are not expected to increase significantly in the foreseeable future, and may actually decline as more forestland comes under professional management.

Construction[134]

The highly diversified activities of the construction industry, ranging from small-scale residential construction to heavy earth moving jobs such as highway, dam, and power plant construction, make this industry a substantial source of non-point pollution in particular locations. The runoff of pollutants from construction sites depends on precipitation, wind, soils, topography, and erosion control measures at each site. The nature and quantity of pollutants leaving a site also depend upon the particular activities being conducted, the construction practices utilized, the extent of disturbed area, the number of people and equipment involved and their impacts on the area, the extent of protective vegetation covering the site, and other similar factors.[135]

The acreage of land disturbed on construction sites is small compared to other non-point sources, such as agricultural lands, but the rate of soil erosion can be 10 times that from agriculture.[136] Moreover, since construction projects usually last from 6 to 18 months, unprotected sites can have a significant effect on local water resources.

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[133] Development Planning and Research Associates, Inc., Environmental Implications of Trends in Agriculture and Silviculture-Volume I: Trend Identification and Evaluation, EPA 600/3-77-121, October 1977, pp. 157-161.

[134] Much of the description in this section is based on: U.S. Environmental Protection Agency, Methods for Identifying and Evaluating the Nature and Extent of Nonpoint Sources of Pollutants, EPA 430/9-73-014, October 1973, Chapter 6.

[135] Thronson, R.E., Nonpoint Source Control Guidance - Construction, EPA Technical Memorandum TECH 27, December 1976, p. 1-1.

Activities typical of construction projects include clearing, grubbing (e.g., removal of tree stumps), pest control, rough grading, facility construction, and restoration of the construction site. Pollutants resulting from such activities can be broadly grouped as sediment, chemical pollutants, and biological pollutants.

Sediment is the main pollutant associated with construction. A major factor responsible for the loss of soil from some construction sites is the clearing of large areas of land at one time, rather than in stages. Often the lack of a well-planned grading schedule results in the exposure of large surfaces during heavy rain seasons when runoff is greatest. An estimated 200 million tons of sediments per year are deposited by surface runoff from urban residential, urban nonresidential, and highway and road construction, with 95 percent being generated by the last source.[137]

The major categories of chemical pollutants from construction operations and materials are petroleum products, pesticides, fertilizers, metals, soil additives, construction chemicals, and miscellaneous wastes (construction debris).

Petroleum products are the largest group of pollutant-producing materials consumed in construction activities. A majority of these materials--oils, grease, fuels, certain solvents--float on the surface of water and spread easily over a wide area. Oils and other petroleum products are readily absorbed by sediment, which is the main carrier of these materials. Sediment contaminated with oil is carried in runoff to receiving streams. The inherent properties of petroleum products make them extremely difficult to control after they enter water bodies. Some impart a persistent odor and taste to water; others can block the transfer of oxygen from the atmosphere into water, resulting in the suffocation of fish and other aquatic organisms. Some contain organometallic compounds and other impurities that can be toxic to fish and other organisms.

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[136] See Table 6-24.

[137] Midwest Research Institute, National Assessment of Water Pollution From Nonpoint Sources, Draft of Final Report, prepared for U.S. Environmental Protection Agency, Contract Number 68-01-2293, November 1975, pp. 16, 24, 25.

The three most commonly used pesticides at construction sites are herbicides, insecticides, and rodenticides. Herbicides are used for removing weeds around the construction area, but their use is minor, since most plants are removed by bulldozers during land clearing and grubbing. The particular pesticide used may depend on the region, climate, and target species. Pesticides enter receiving waters in runoff from construction sites, or because improper methods of application result in direct contamination of water.

One of the best ways to reduce soil erosion from construction sites is to establish vegetation on exposed soils as soon as possible. Fertilizers are normally used to promote vegetative growth, and thus to prevent erosion, but heavy use can add nitrogen and phosphorus to nearby streams.

Metallic wastes from construction weather to oxides and salts that can be toxic to aquatic organisms. The concern over metal pollution of water bodies is associated mostly with the heavy metals (mercury, lead, zinc, silver, cadmium, arsenic, copper, aluminum, iron, etc.); about 5 million tons of heavy metals per year are estimated to be deposited in surface waters by all nonpoint sources.[138]

The environmental effects of soil additives--chemicals and other materials applied to the soil during construction to obtain desired soil characteristics--are not known. These additives are used to control the amount of moisture absorbed by roadway surfaces, to reduce shrinking and expanding of clay soils, and to increase the firmness of soils. Common additives include lime, fly ash, asphalt, phosphoric acid, salt, and calcium chloride. If the materials are carried in runoff from construction sites, they could alter the quality of receiving waters. However, extensive work has not been conducted to determine environmental effects.

Construction chemicals include those used for gluing, sealing cracks, treating surfaces, dyeing and cleaning, and thinning oils and paints. The amounts of chemicals leaving construction sites as pollutants have not been established and their total effects on water quality are unknown.

Finally, biological pollutants resulting from construction activity include soil organisms and organisms of human and animal origin, such as bacteria, fungi, and viruses. Most biological pollutants are found in the topsoil layer. Sediments and runoff are the major carriers of these organisms, which are more serious on construction sites where improper sanitary conditions exist.

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[138] Midwest Research Institute, National Assessment of Water Pollution From Nonpoint Sources, Draft of Final Report, prepared for U.S. Environmental Protection agency, Contract Number 68-01-2293, November 1975, pp. 16, 24, 25.

Construction activities are estimated to affect about 10 percent of the EPA-designated hydrological drainage basins in the United States (Figure 6-31). The Northwest Region (Federal Region X) and the New England, New York-New Jersey, and Middle Atlantic Regions (Federal Regions I, II, and III) have the most affected basins--about 25 and 15 percent, respectively--while the South Central and West Regions (Federal Regions VI and IX) have not reported any basins affected by construction activities.

From 1975 to 2000, a growing population will demand the development of land to accommodate new housing, roads, utilities, communications, and sewage systems, all of which yield construction-related pollution. In both of our scenarios, construction is expected to double between 1975 and 2000. Thus, although many states and counties require runoff controls on construction sites,[139] pollution from this source will remain a cause of concern.

6.4 IMPLICATIONS OF WATER POLLUTION TRENDS

6.4.1 Point and Non-point Sources

Deterioration of our nation's water quality results from both point and non-point discharges, as has been described in the preceding sections of this chapter. While there is sometimes little distinction between the two types of sources, in general point source pollution is associated with discharges from municipal and industrial sources where the wastes originate from a pipe or other conduit. Non-point source pollution, on the other hand, is far more diffuse and stems from stormwater runoff from urban, agricultural, forested, construction, and mining areas, as well as from natural background sources.

Point source pollution is often more intensive and concentrated than non-point pollution and can discharge large quantities of pollutants in one stream segment. Non-point source pollution is generally more extensive and accompanied by high dilution may pollute more stream miles in a given water basin. Point sources are also of primary concern during low-flow stream conditions when non-point sources are relatively inactive. Conversely, non-point pollutants are freely discharged during high-flow stream conditions when point sources have less impact on water quality. Thus, while point source pollution is

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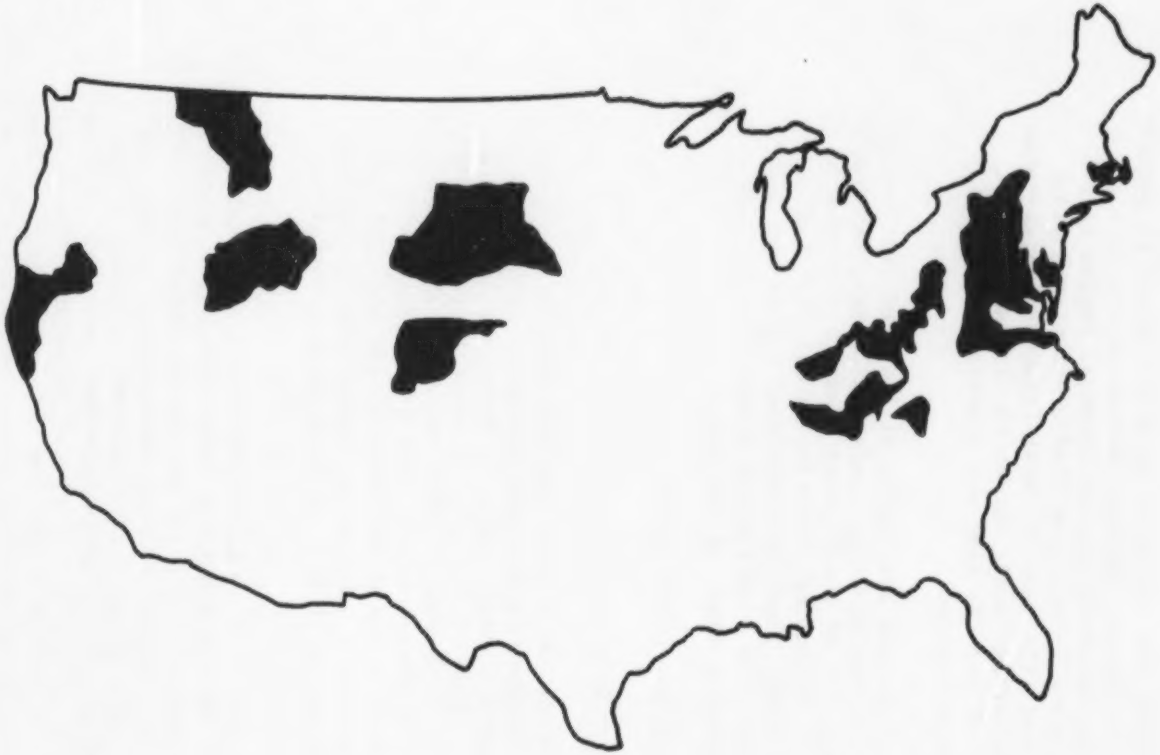
[139] U.S. Environmental Protection Agency, National Water Quality Inventory/1977 Report to Congress, EPA 440/4-78-001, October 1978, pp. 1-3.



NOTE: Basins where some (or all) stream segments have a problem with pollution from construction activities that is not minor or insignificant, according to state officials. Affected basins are shaded.

Source: U.S. Environmental Protection Agency, National Water Quality Inventory/ 1977 Report to Congress, EPA 440/4-78-001, Washington, D.C., October 1978, p. 21.

FIGURE 6-31
EPA-DESIGNATED HYDROLOGICAL DRAINAGE BASINS
AFFECTED BY POLLUTION FROM CONSTRUCTION ACTIVITIES
1977

generally continuous, non-point source pollution is primarily related to storm events. Nevertheless, non-point source can release substantial amounts of pollutants. A severe 15-minute storm can sometimes create more pollution than a particular point source over a year.

The nation's most widespread water quality problems are high levels of nutrients, bacterial pollution, high concentrations of suspended sediment, and heavy loadings of oxygen-demanding material (BOD) and consequent oxygen depletion in streams. In addition, toxic pollutants (heavy metals, nonmetallic toxics, and pesticides) are of particular concern because of their persistence, toxic effects at very low concentrations, and ability to enter the aquatic food chain, and because of the difficulty of controlling these substances by conventional municipal treatment technology.[140]

Both point and non-point sources contribute to these pollutant problems; the relative impact that particular sources have on water quality is different, although not clearly known. The type, magnitude and concentration of pollutants generated by each source, as well as the assimilated capacities of streams and the pollutants released by natural background sources, must be considered in determining the water quality impacts from point and non-point sources. However, because point sources are discrete in nature and non-point sources are diffuse, water quality impacts are easier to assess from point source releases than from non-point source releases. Nevertheless, it is generally agreed that point and non-point sources do affect water quality in a variety of ways.

For example, excess suspended solids from non-point sources currently affect more than half of our drainage basins, while excess suspended solids from point sources affect about one-third (Figure 6-32). Similarly, dissolved solids from non-point sources generally affect twice as many basins as do dissolved solids from point sources (Figure 6-33). These patterns reflect differences in the geographic distribution of major sources.

In contrast, pollution problems associated with oxygen depletion (measured as BOD discharge) is caused more by point sources than by non-point sources because of municipal and industrial discharges; almost 80 percent of the basins are affected by point sources of BOD, compared to about 50 percent from non-point sources, notably agriculture and urban runoff (Figure 6-34).

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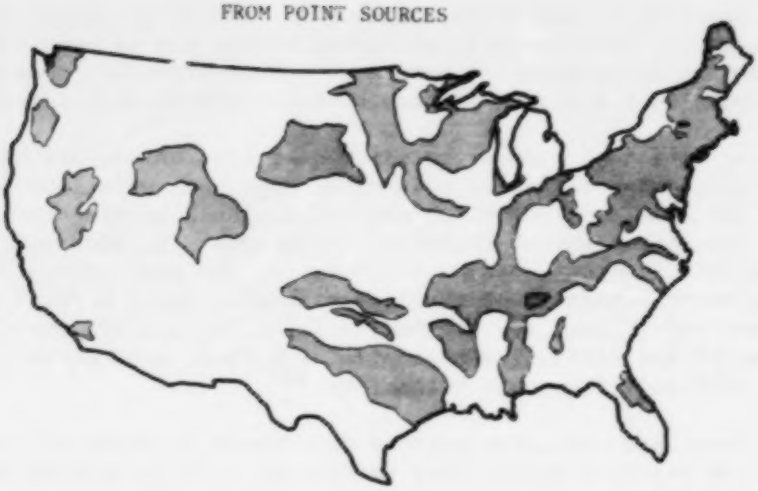
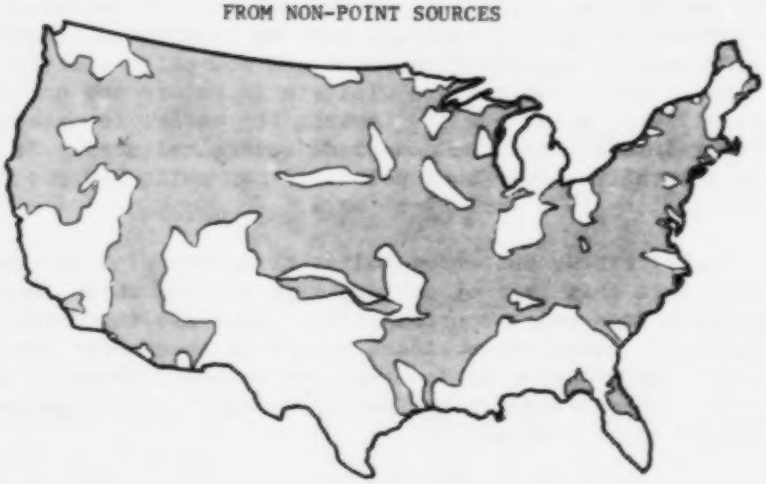
[140] U.S. Environmental Protection Agency, National Water Quality Inventory/1977 Report to Congress, EPA 440/4-78-001, October 1978, pp. 1-3..



FROM POINT SOURCES



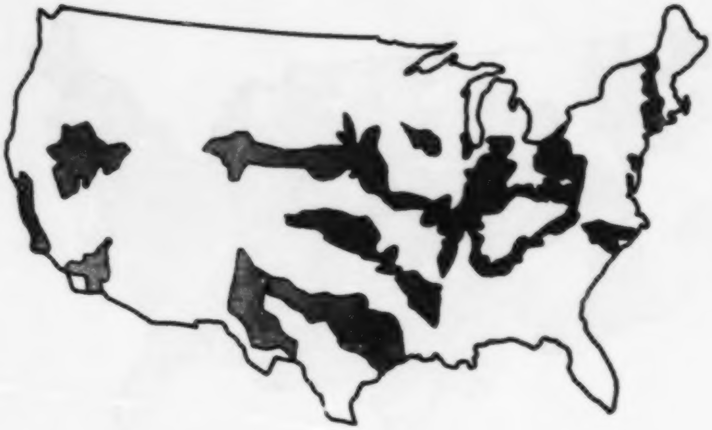
FROM NON-POINT SOURCES

NOTE: Basins where some (or all) stream segments have a problem with suspended solids that is not minor or insignificant, according to state officials. Affected basins are shaded.

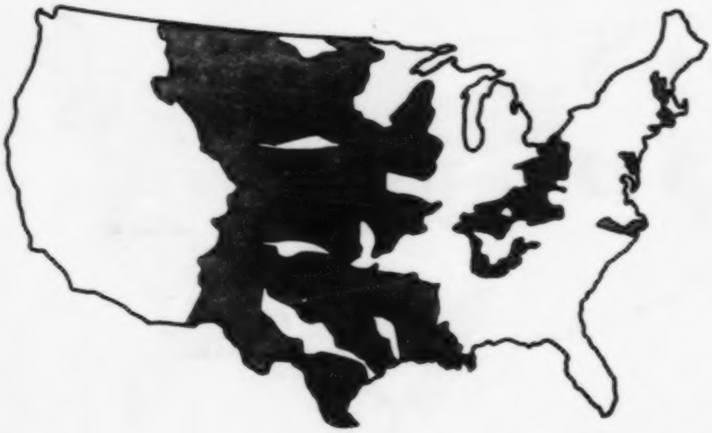
Source: U.S. Environmental Protection Agency, National Water Quality Inventory/1977 Report to Congress, EPA 440/4-78-001, Washington, D.C., 1978, p. 4.

FIGURE 6-32
EPA-DESIGNATED HYDROLOGICAL DRAINAGE BASINS
AFFECTED BY SUSPENDED SOLIDS
1977

FROM POINT SOURCES



FROM NON-POINT SOURCES

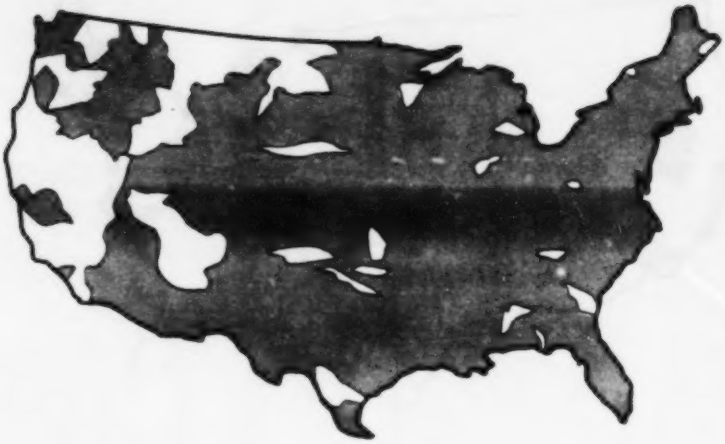


NOTE: Basins where some (or all) stream segments have a problem with dissolved solids that is not minor or insignificant, according to state officials. Affected basins are shaded.

Source: U.S. Environmental Protection Agency, National Water Quality Inventory/1977 Report to Congress, EPA 440/4-78-001, Washington, D.C., October 1978.

FIGURE 6-33
EPA-DESIGNATED HYDROLOGICAL DRAINAGE BASINS
AFFECTED BY DISSOLVED SOLIDS
1977

FROM POINT SOURCES



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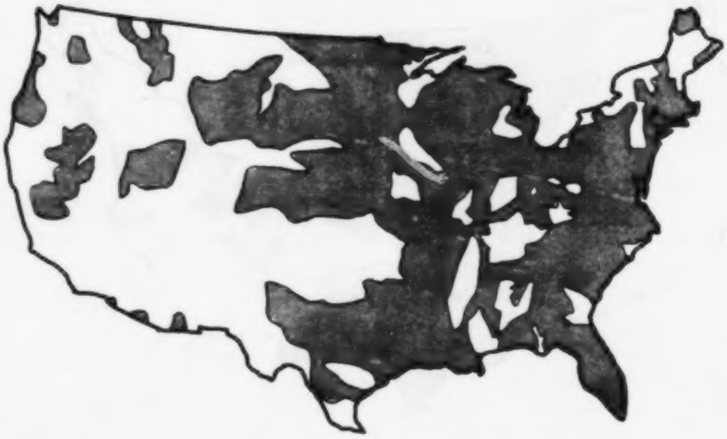

NOTE: Basins where some (or all) stream segments have a problem with biochemical oxygen demand that is not minor or insignificant, according to state officials. Affected basins are shaded.

Source: U.S. Environmental Protection Agency, National Water Quality Inventory/1977 Report to Congress, EPA 440/4-78-001, Washington, D.C., October 1978.

FIGURE 6-34
EPA-DESIGNATED HYDROLOGICAL DRAINAGE BASINS
AFFECTED BY BIOCHEMICAL OXYGEN DEMAND
1977

Problems with toxic pollutants are also associated more with point than non-point sources, with point sources affecting about twice as many basins (Figure 6-35). Industrial activities are the primary sources of toxic point source releases. Pesticides in agricultural runoff and heavy metals in urban and mining runoff are the main non-point sources of toxic releases.

Water pollution by nutrient releases is attributable about equally to point and non-point sources (Figure 6-36). Municipal discharges and combined sewer overflows are the principal point source contributors, while agricultural and urban runoff are the primary non-point source contributors.

Of all pollutants, oil and grease affect the smallest number of basins across the United States from both point and non-point sources (Figure 6-37). Heavy industrial activity and urban runoff are the primary contributors to this pollution problem, so it is not surprising to find that the New England, New York-New Jersey, Middle Atlantic, and Great Lakes Regions (Federal Regions I, II, III, and V) have the most widespread problems from oil and grease releases.

Many of the municipal treatment plants and other point source pollution control facilities built during the last decade are just beginning to yield benefits. Early evaluation of their effectiveness reveals that water quality is improving in many specific places, particularly the urban belt south of the Great Lakes.[141] Although continued improvement may be expected over the next several years, new toxic pollutants will likely be discovered in the future given the ever increasing sophistication of pollutant monitoring equipment. Moreover, because health effects are likely to be observed at lower and lower concentrations for both new and existing toxic compounds, toxic pollutants from point source discharges will continue to be an important concern for the future.

In addition, control of non-point source pollution has not progressed as fast as control of point sources. In recent years, non-point pollution has received more attention as industrial and municipal point source discharge are brought under control. But, levels of suspended solids, nutrients, and BOD in our streams and lakes have not shown noticeable improvements,[142] because non-point sources are responsible for much of these pollutants. Indications are that non-point pollutant discharges would probably increase in the absence of control measures. Thus, non-point source pollution problems are not likely to be mitigated unless a concerted effort is

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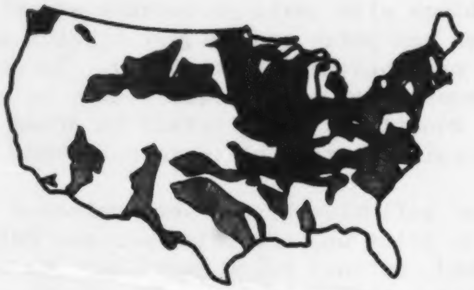
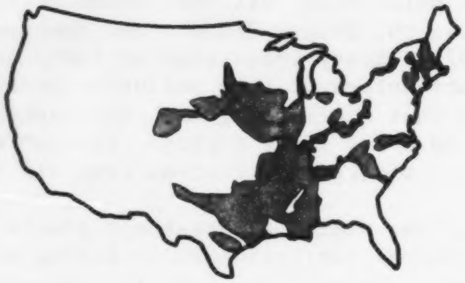
[141] U.S. Geological Survey, National Stream Quality Accounting Network (NASQAN), data for 1975 to 1977. (To be released in yearly sections as open file reports).

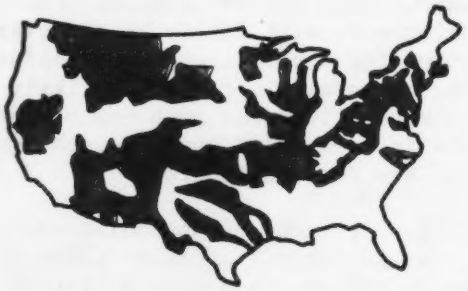
[142] Ibid.



FROM POINT SOURCES



FROM NON-POINT SOURCES (PESTICIDES ONLY)



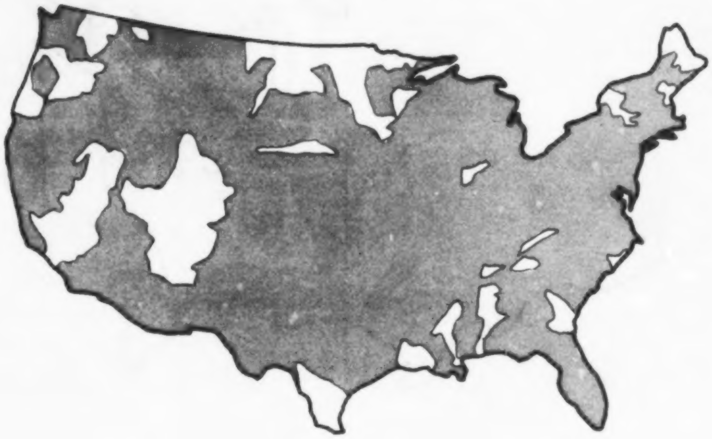
FROM NON-POINT SOURCES (TOXICS OTHER THAN PESTICIDES)

NOTE: Basins where some (or all) stream segments have a problem with toxic pollutants that is not minor or insignificant, according to state officials. Affected basins are shaded.

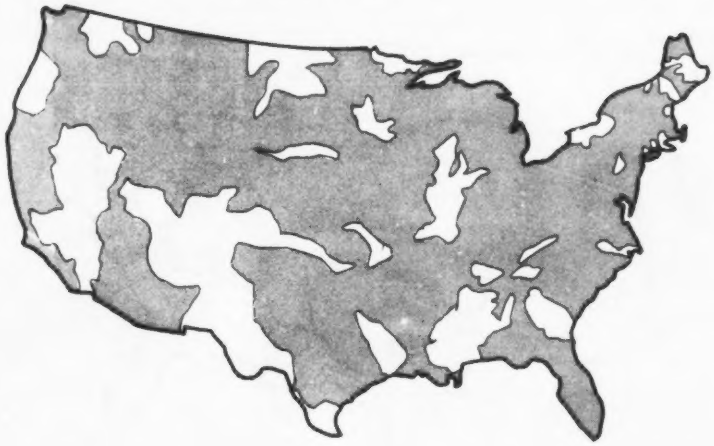
Source: U.S. Environmental Protection Agency, National Water Quality Inventory/1977 Report to Congress, EPA 440/4-78-001, Washington, D.C., October 1978, p. 5.

FIGURE 6-35
EPA-DESIGNATED HYDROLOGICAL DRAINAGE BASINS
AFFECTED BY TOXIC POLLUTANTS
1977

FROM POINT SOURCES



FROM NON-POINT SOURCES

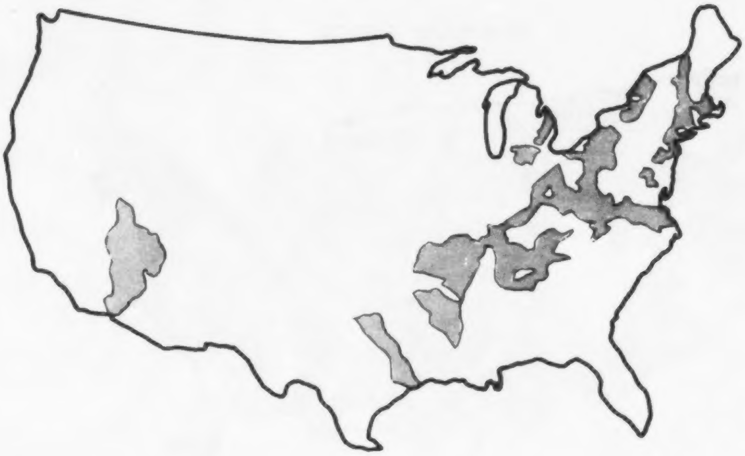


NOTE: Basins where some (or all) stream segments have a problem with nutrients that is not minor or insignificant, according to state officials. Affected basins are shaded.

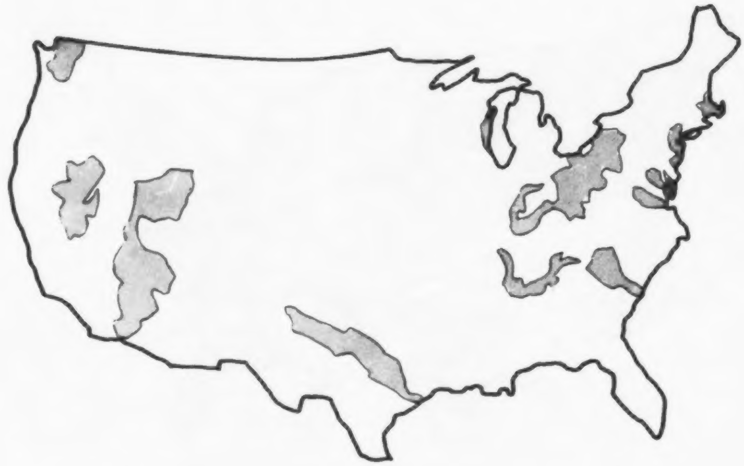
Source: U.S. Environmental Protection Agency, National Water Quality Inventory/1977 Report to Congress, EPA 440/4-78-001, Washington, D.C., October 1978.

FIGURE 6-36
EPA-DESIGNATED HYDROLOGICAL DRAINAGE BASINS
AFFECTED BY NUTRIENTS
1977

FROM POINT SOURCES



FROM NON-POINT SOURCES



NOTE: Basins where some (or all) stream segments have a problem with oil and grease that is not minor or insignificant, according to state officials. Affected basins are shaded.

Source: U.S. Environmental Protection Agency, National Water Quality Inventory/1977 Report to Congress, EPA 440/4-78-001, Washington, D.C., 1978.

FIGURE 6-37
EPA-DESIGNATED HYDROLOGICAL DRAINAGE BASINS
AFFECTED BY OIL AND GREASE
1977

made to reduce pollutant discharges to surface waters by controlling the problem at the source--in other words, by promoting the widespread use of Best Management Practices.

6.4.2 Comparison of Point and Selected Non-point Source Discharge Trends

This section compares water pollutant discharge trends for those pollutants and those point and selected non-point sources currently included in the SEAS model. For point sources, this includes most municipal and industrial discharges (although with limitations, as discussed Section 6.2). For non-point sources, this includes agricultural runoff (limited, however, to surface runoff from the production of eight major crop commodities) and urban runoff.

It should again be noted that point source trends projections are predicated on full compliance by point source dischargers with EPA effluent guideline standards; hence, the projections may be considered uncertain and perhaps optimistic. On the other hand, the non-point projections are based on an assumption, for urban runoff, of no control measures and, for agricultural runoff, of no change in the proportion of cropland adequately treated for soil conservation measures and a continuation of recent trends in pesticide and fertilizer use.

The inclusion of only two non-point sources in our projections underestimates pollutant discharges from non-point sources. This bias is most critical for BOD, nitrogen, and phosphorus, because some sizable non-point sources--pastureland, rangeland, silviculture, and construction--that significantly contribute to these releases are not included. Also, because agricultural runoff does not include the effects of irrigation return flows, suspended and dissolved solids in the 17 western states are also underestimated. In addition, because the above activities, as well as mining, are expected to grow rapidly by 2000, growth of non-point source discharges from 1975 to 2000 is somewhat underestimated.

These deficiencies should be kept in mind while reviewing the point and selected non-point source discharge trends presented below.[143]

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[143] Trends in pesticide discharges are not included here because SEAS projects these discharges for agricultural runoff only (see Section 6.3.3).

General Trends

In the SEAS estimates for 1975, the selected non-point sources of pollution discharged a far greater amount of the total suspended solids and total dissolved solids releases than point sources (Table 6-39). Although point sources of pollution appear to predominate in releases of other pollutants, this is simply because the sizable non-point sources discussed above are not included. Indeed, if projections of non-point source releases included all non-point sources, most BOD, nitrogen, and phosphorus would derive from non-point sources. Point sources would still, in all probability, predominate in oil and grease releases.[144]

In the High Growth Scenario from 1975 to 2000, releases of BOD, phosphorus, and oil and grease are projected to decline for the three sources considered, while pollutant releases of suspended solids, dissolved solids, and nitrogen are projected to increase. Underlying these overall trends is an increase in the selected non-point source pollutant releases, offset by a general decline in point source pollutant releases. One notable exception is point source releases of dissolved solids, which are projected to increase faster than any other point or selected non-point source pollutant.[145]

In the Low Growth Scenario, pollutant releases--point and selected non-point--are expected to increase at a slower rate (or decline at a faster rate) due to slower growth in population and economic activity.

Analysis of Trends[146]

In 1975, four regions--Southeast, Great Lakes, South Central, and Central Regions (Federal Regions IV, V, VI, and VII)--generated about 85 percent of the suspended and dissolved solids discharges (Table 6-40). Of the three sources included, the major contributor to these discharges was agricultural runoff, due to the sizable

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[144] Based on information in Midwest Research Institute, National Assessment of Water Pollution From Nonpoint Sources, Draft of Final Report, prepared for U.S. Environmental Protection Agency, Contract No. 68-01-2293, November 1975. Also U.S. Environmental Protection Agency, "Pilot Assessment of Ambient Conditions, Part II: Pollution Sources and Trends," December 11, 1979.

[145] See Section 6.2.4 for further details.

[146] BOD, nitrogen, and phosphorus releases are not included in this discussion because the understatement of non-point source pollution prevents meaningful detailed analysis.

TABLE 6-39
TRENDS IN DISCHARGES OF MAJOR WATER POLLUTANTS FROM POINT AND SELECTED NON-POINT SOURCES[a]

	1975	2000	
	Quantity (10^3 tons)	High Growth Percent of 1975 Value	Low Growth Percent of 1975 Value
BOD			
Point	2,800	62	56
Selected Nonpoint[b]	1,000	121	107
Total Suspended Solids			
Point	5,700	31	28
Selected Nonpoint[c]	100,000	121	104
Total Dissolved Solids			
Point	7,900	212	177
Selected Nonpoint[c]	44,000	121	104
Nitrogen			
Point	790	111	103
Selected Nonpoint[b]	64	123	114
Phosphorus			
Point	290	81	76
Selected Nonpoint[b]	8	150	125
Oil and Grease			
Point	480	71	56
Selected Nonpoint[d]	86	122	114

---

[a] Assumes point sources are controlled (i.e., net discharges) and non-point sources are not controlled (i.e., gross discharges).

[b] Includes urban runoff and agricultural runoff for eight major crop commodities only. Thus, total gross non-point source pollutant releases are very much understated. Indeed, if all non-point sources were included, the net point source releases shown would be far less than gross non-point source releases (see text for further explanation).

[c] Includes urban runoff and agricultural runoff for eight major crop commodities only. Thus, total gross non-point source pollutant release are understated. Indeed, if all non-point sources were included, the net point source contribution to the national total would be even less than is now indicated (see text for further explanation).

[d] Includes urban runoff only. If all non-point sources are included, it is still expected that net point source discharges would dominate (see text for further explanation).

TABLE 6-40
TRENDS IN REGIONAL DISCHARGES OF TOTAL SUSPENDED SOLIDS AND TOTAL DISSOLVED SOLIDS[a]
HIGH GROWTH SCENARIO
1975 AND 2000

Region	Total Suspended Solids				Total Dissolved Solids			
	1975		2000		1975		2000	
	Quantity (10^3 tons)	Percent of National Total	Percent of 1975 Value	Percent of National Total	Quantity (10^3 tons)	Percent of National Total	Percent of 1975 Value	Percent of National Total
I. **New England**	950	1	101	1	640	1	166	2
II. **New York-New Jersey**	1,600	2	101	1	1,200	2	142	3
III. Middle Atlantic	6,000	6	119	6	3,900	7	149	8
IV. Southeast	25,000	24	116	24	12,000	23	136	23
V. Great Lakes	25,000	24	131	27	13,000	24	139	25
VI. South Central	17,000	16	106	14	7,700	15	131	14
VII. Central	24,000	23	113	22	11,000	21	117	18
VIII. Mountain	2,000	2	96	2	1,300	2	137	2
IX. West	970	1	99	1	800	2	189	2
X. Northwest	2,600	2	117	2	1,200	2	163	3
Total[b]	106,000	100	116	100	52,000	100	135	100

[a] Includes point sources, urban runoff, and agricultural runoff, and reflects the control of point sources (i.e., net discharges) and the lack of control of nonpoint sources (i.e., gross discharges). See text for interpretation.

[b] Rounding may create inconsistencies in addition.

amounts of crop production in these regions. Only three regions in the United States--the New England, New York-New Jersey, and West Regions (Federal Regions I, II, and IX)--generated more suspended and dissolved solid releases in 1975 from urban runoff and/or point sources than from agricultural runoff.

Suspended solid releases in Federal Regions I, II, III, V, and VII were greater from urban runoff than from point sources in 1975, while the opposite was the case in the other five regions (Figure 6-38). Dissolved solids releases, on the other hand, were more prevalent from point sources than from urban runoff in 1975 in all but three regions (Federal Regions I, II, and X) (Figure 6-39).

From 1975 to 2000 in the High Growth Scenario, both suspended and dissolved solids discharges are expected to increase, at differing regional rates that reflect different economic bases and different trends in economic and population growth. Suspended solids releases are projected to increase most rapidly in the Great Lakes Region (Federal Region V), reflecting increases in agricultural acreage. Dissolved solids releases are projected to increase most rapidly in the West Region (Federal Region IX), reflecting increases in point source discharges. However, no major shift is projected in the regional distributions of either total suspended solid or total dissolved solid releases.

The relative contributions of point and the selected non-point sources, however, are expected to change in certain regions between 1975 and 2000 in the High Growth Scenario. For example, in the West Region (Federal Region IX), point sources contributed the most to suspended solids releases in 1975 but are expected to contribute the least by 2000. On the other hand, in the Middle Atlantic and Mountain Regions (Federal Regions III and VIII), agricultural runoff contributed the most to dissolved solids releases in 1975 but, by 2000, point sources are projected to contribute the most.

In the Low Growth Scenario, by 2000, regional suspended solids releases are generally projected to decline or remain at 1975 levels. The one exception is in the Great Lakes Region (Federal Region V), where, as in the High Growth Scenario, suspended solids releases are projected to increase between 1975 and 2000 due to increased agricultural acreage. Dissolved solids releases are projected in the Low Growth Scenario to increase more slowly; in two regions--Central and Mountain (Federal Regions VII and VIII)--no significant change is projected between 1975 and 2000. By 2000, the regional distributions for total suspended solids and total dissolved solids are projected to be the same as in the High Growth Scenario.

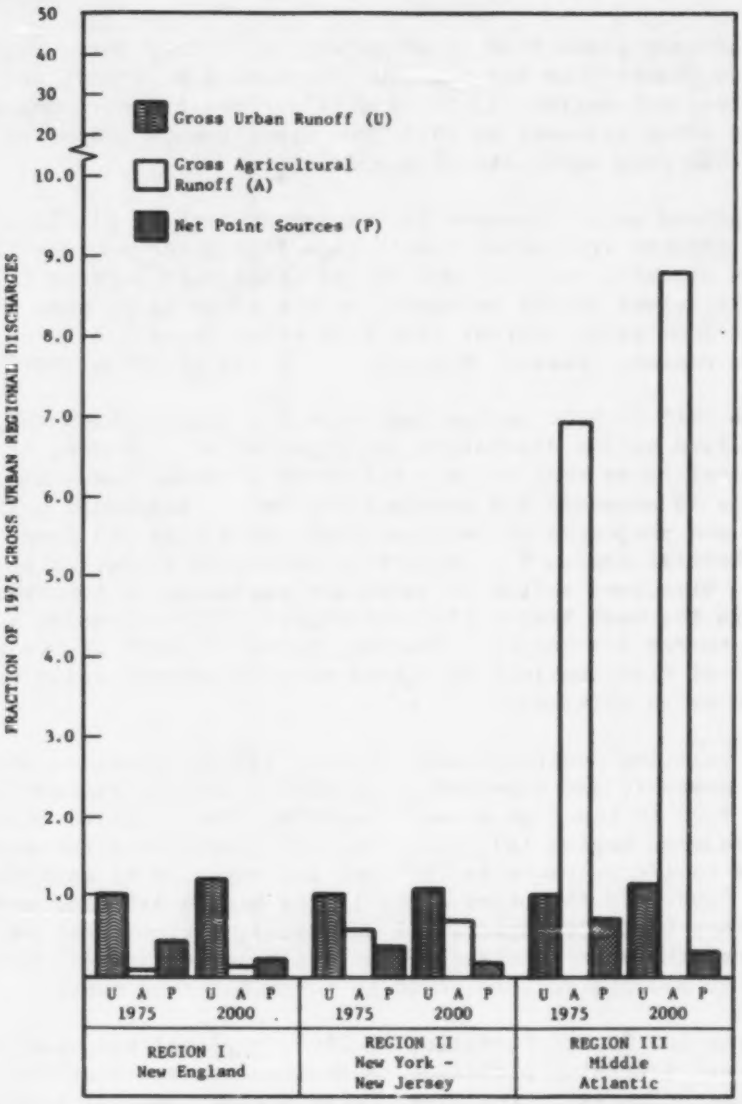

FIGURE 6-38
TRENDS IN REGIONAL DISCHARGES OF TOTAL SUSPENDED SOLIDS BY POLLUTING SOURCE HIGH GROWTH SCENARIO 1975 AND 2000

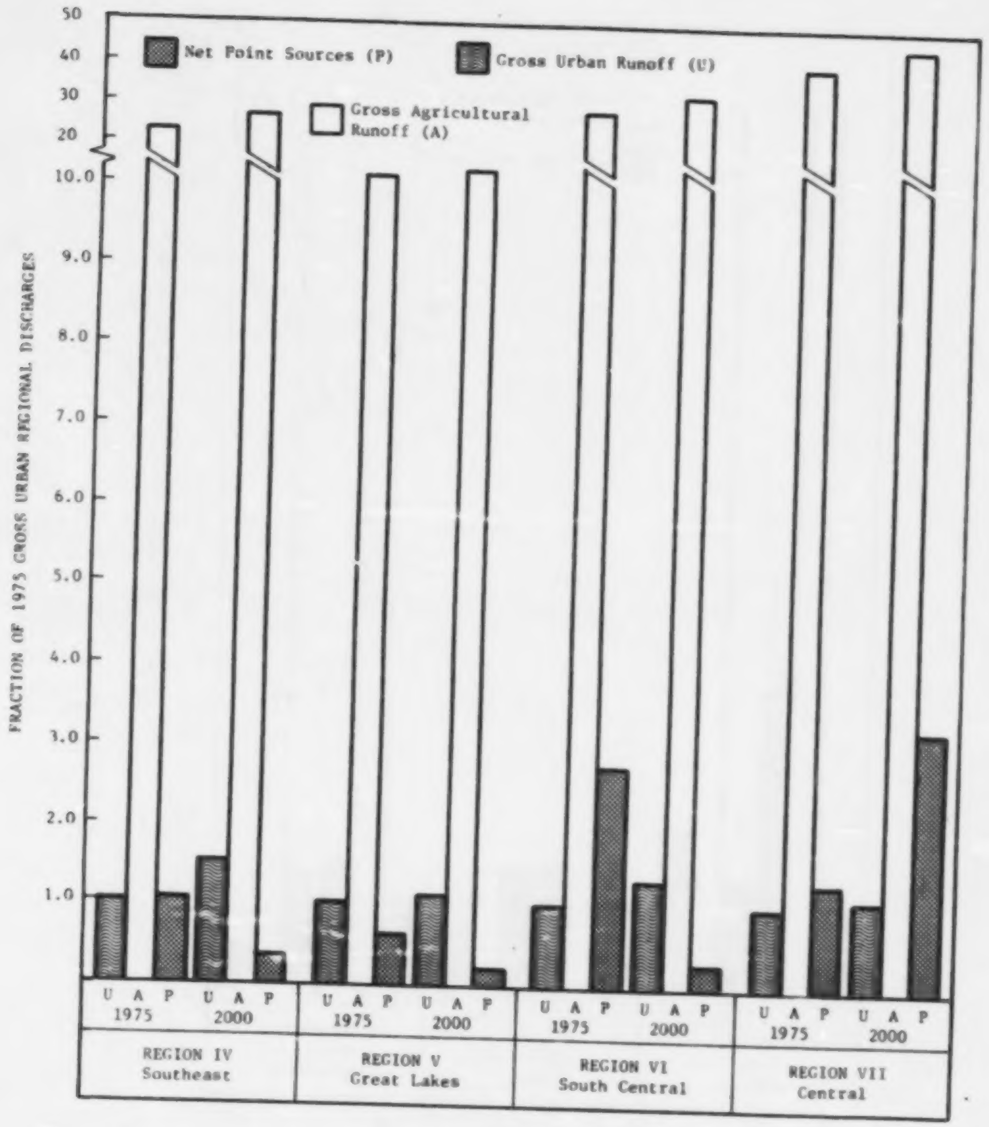

FIGURE 6-38 (CONTINUED)
TRENDS IN REGIONAL DISCHARGES OF TOTAL SUSPENDED SOLIDS BY POLLUTING SOURCE HIGH GROWTH SCENARIO 1975 AND 2000

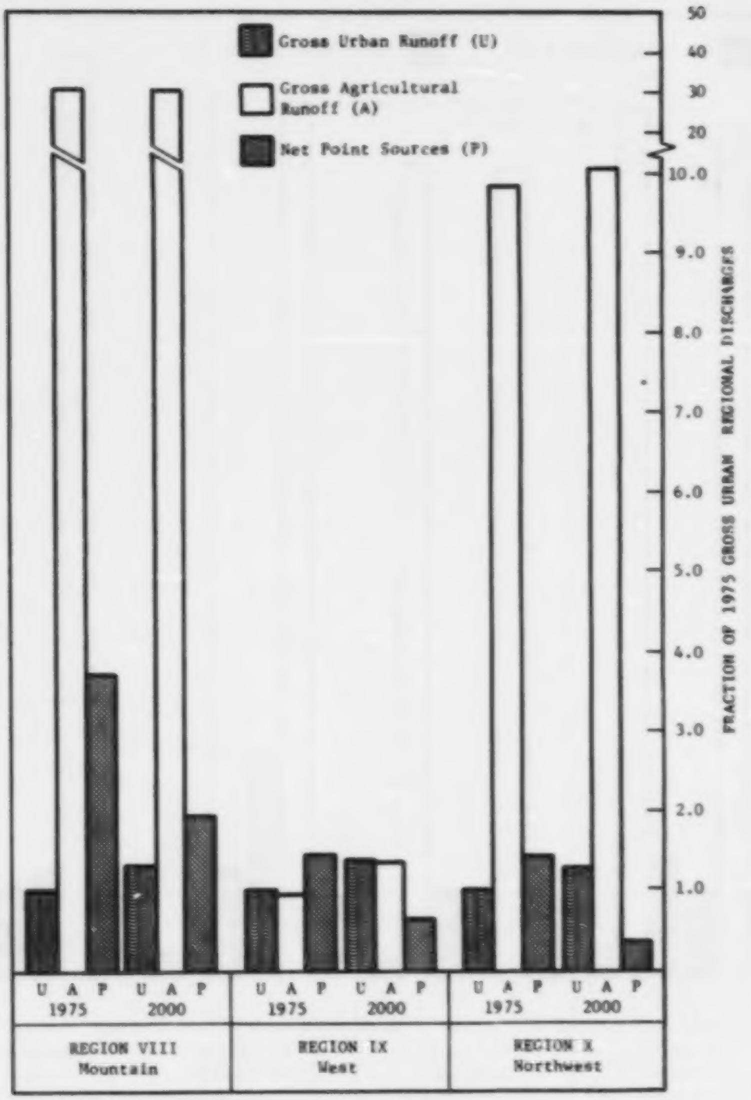

FIGURE 6-38 (CONCLUDED)
TRENDS IN REGIONAL DISCHARGES OF TOTAL SUSPENDED SOLIDS BY POLLUTING SOURCE HIGH GROWTH SCENARIO 1975 AND 2000

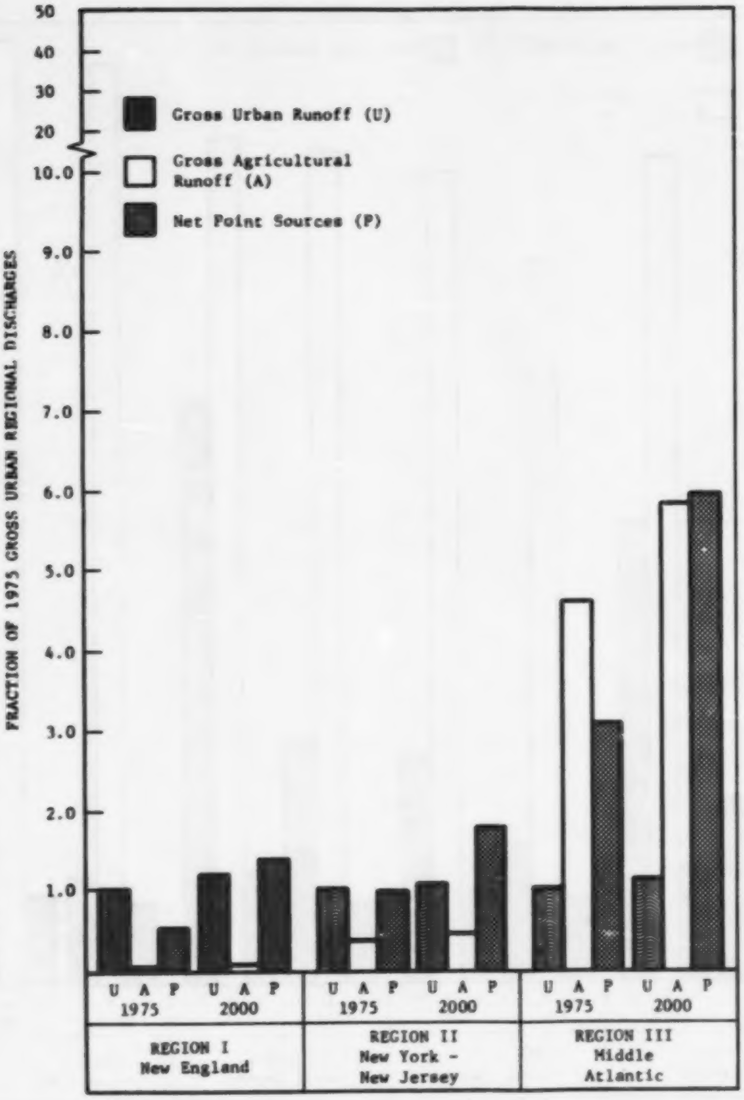

FIGURE 6-39
TRENDS IN REGIONAL DISCHARGES OF TOTAL DISSOLVED SOLIDS BY POLLUTING SOURCE HIGH GROWTH SCENARIO 1975 AND 2000

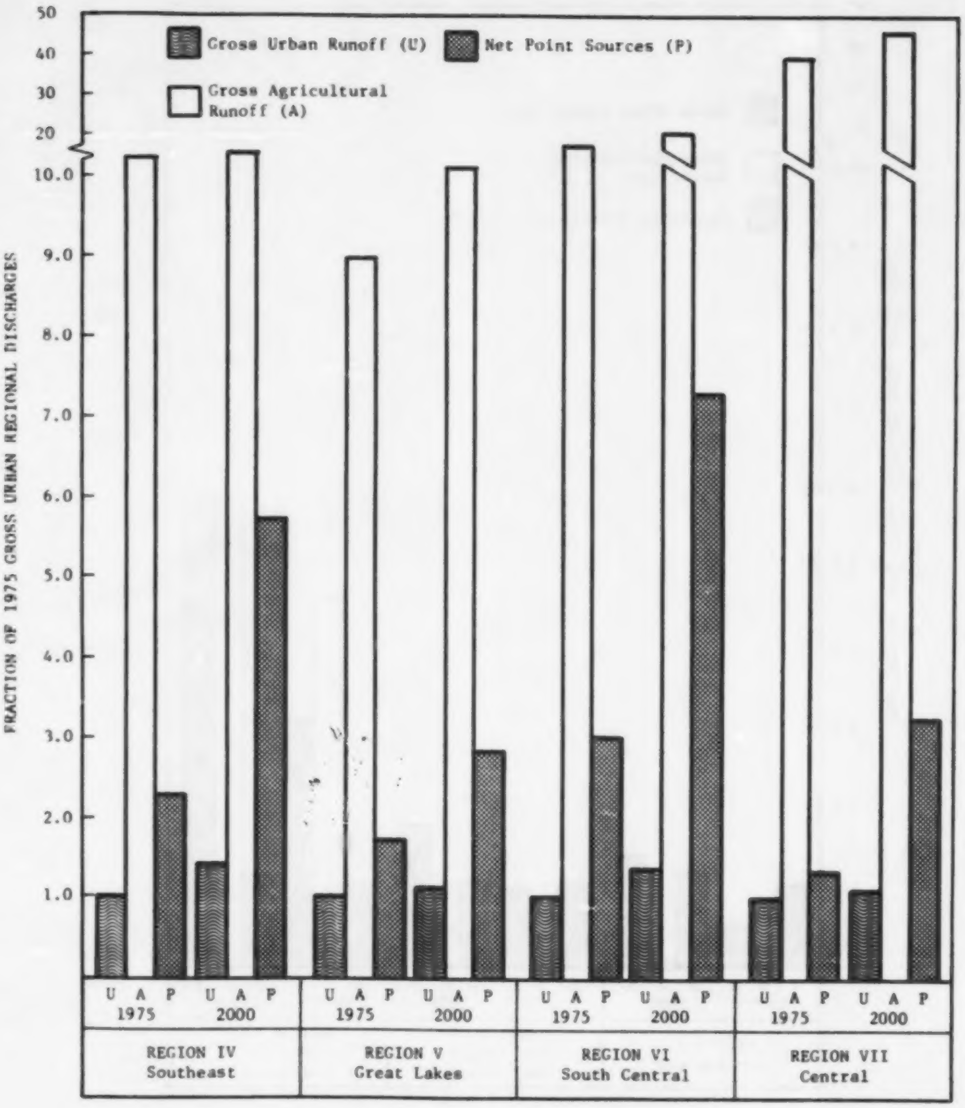

FIGURE 6-39 (CONTINUED)
TRENDS IN REGIONAL DISCHARGES OF TOTAL DISSOLVED SOLIDS BY POLLUTING SOURCE HIGH GROWTH SCENARIO 1975 AND 2000

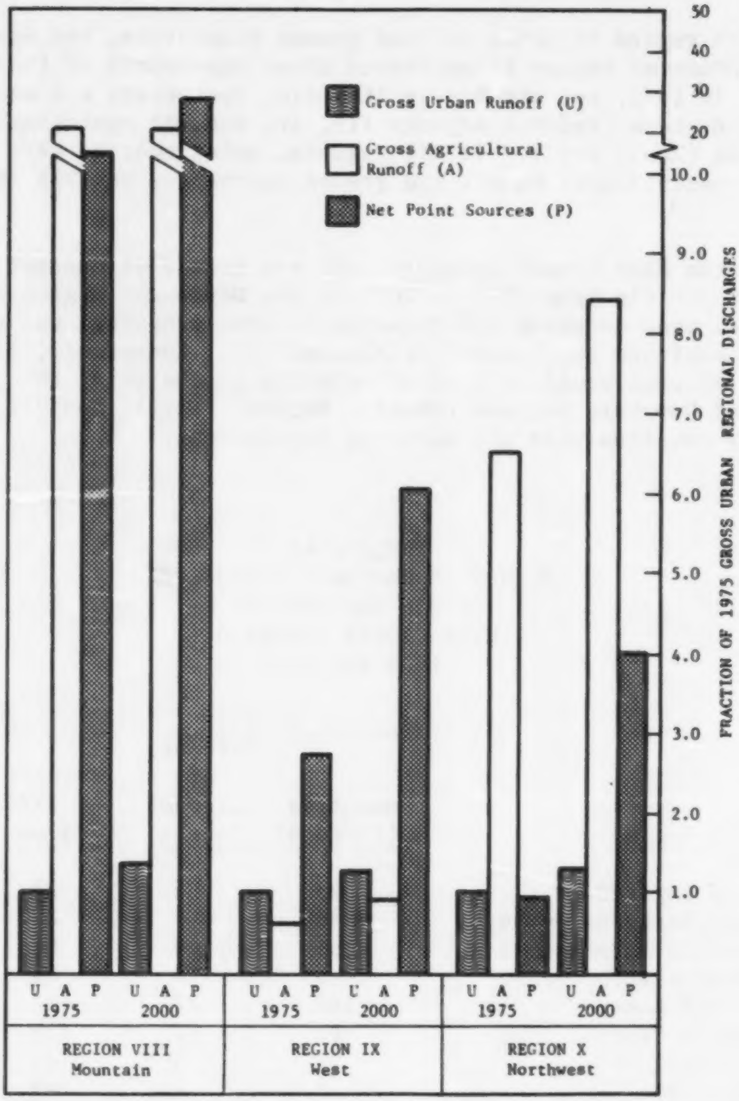

FIGURE 6-39 (CONCLUDED)
TRENDS IN REGIONAL DISCHARGES OF TOTAL DISSOLVED SOLIDS BY POLLUTING SOURCE HIGH GROWTH SCENARIO 1975 AND 2000

With regard to total oil and grease discharges, the Great Lakes Region (Federal Region V) generated about one-fourth of the discharges in 1975, and the Middle Atlantic, Southeast, and South Central Regions (Federal Regions III, IV, and VI) contributed about one-third (Table 6-41). In all regions, point sources were the primary contributors to oil and grease discharges in 1975 (Figure 6-40).

In the High Growth Scenario, oil and grease discharges are projected to triple from 1975 to 2000 in the Northwest Region (Federal Region X) even assuming all required control measures, due primarily to the continued development of Alaskan oil. Conversely, oil and grease releases could be reduced markedly in the Great Lakes, Central, and Mountain Regions (Federal Regions V, VII, and VIII) if industry complies with all existing regulations.

TABLE 6-41
TRENDS IN REGIONAL DISCHARGES
OF OIL AND GREASE[a]
HIGH GROWTH SCENARIO
1975 AND 2000

	Region	1975		2000	
		Quantity (10^3 tons)	Percent of National Total	Percent of 1975 Value	Percent of National Total
I	New England	28	5	77	5
II	New York-New Jersey	46	8	82	9
III	Middle Atlantic	61	10	66	9
IV	Southeast	55	10	83	10
V	Great Lakes	160	27	32	11
VI	South Central	68	12	113	17
VII	Central	22	4	40	2
VIII	Mountain	7	1	45	1
IX	West	27	5	78	5
X	Northwest	8	1	299	5
	Total[b]	560	100	79	100

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[a] Includes point sources and urban runoff, and reflects the control of point sources (i.e., net discharges) and the lack of control of non-point sources (i.e., gross discharges). See text for interpretation of these data.

[b] Rounding may create inconsistencies in addition.

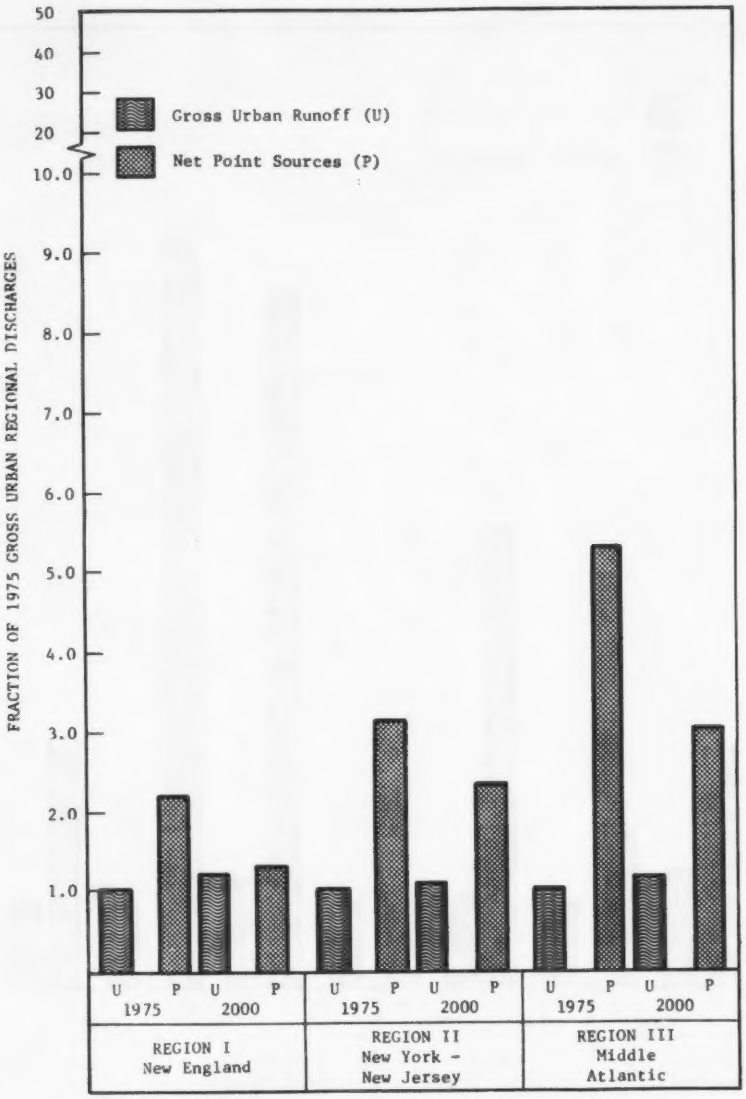

FIGURE 6-40
TRENDS IN REGIONAL DISCHARGES OF OIL AND GREASE BY POLLUTING SOURCE HIGH GROWTH SCENARIO 1975 AND 2000

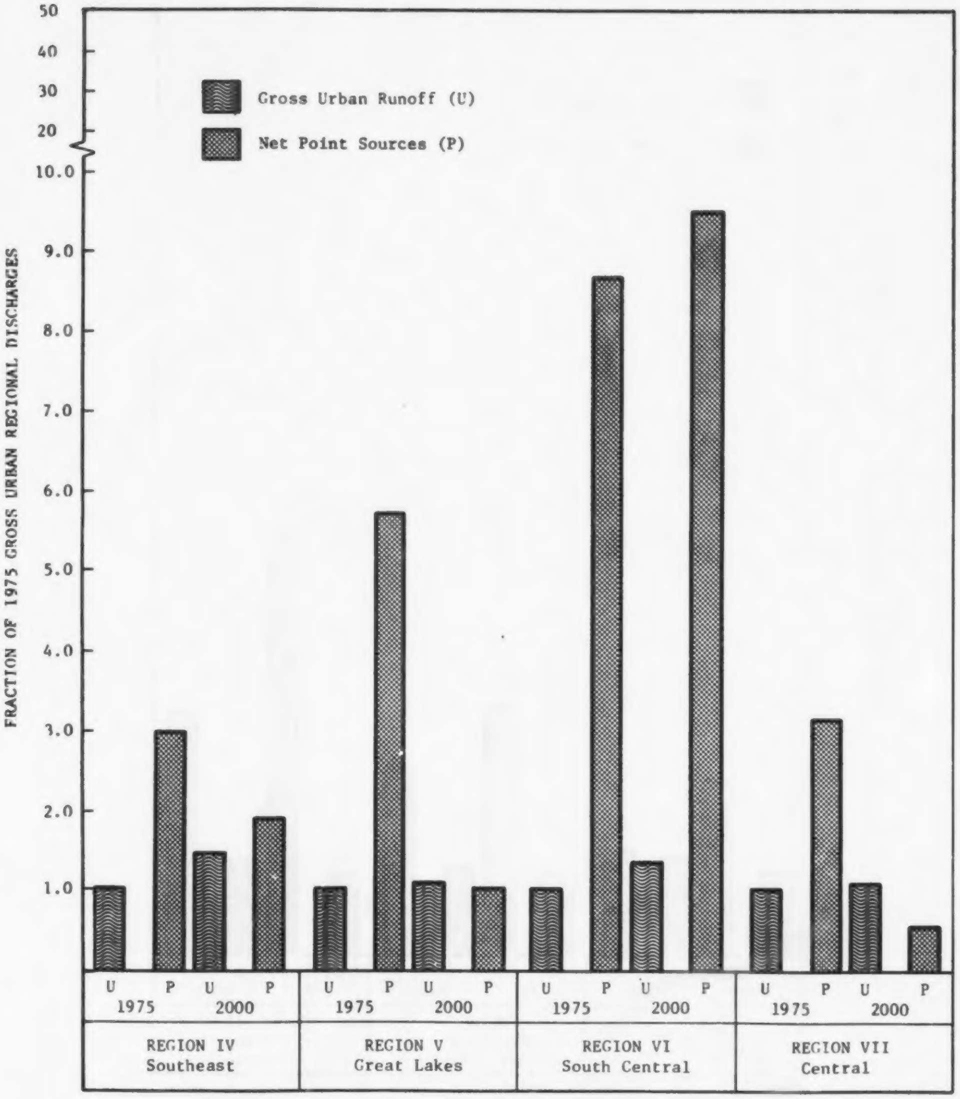

FIGURE 6-40 (CONTINUED)
TRENDS IN REGIONAL DISCHARGES OF OIL AND GREASE BY POLLUTING SOURCE HIGH GROWTH SCENARIO 1975 AND 2000

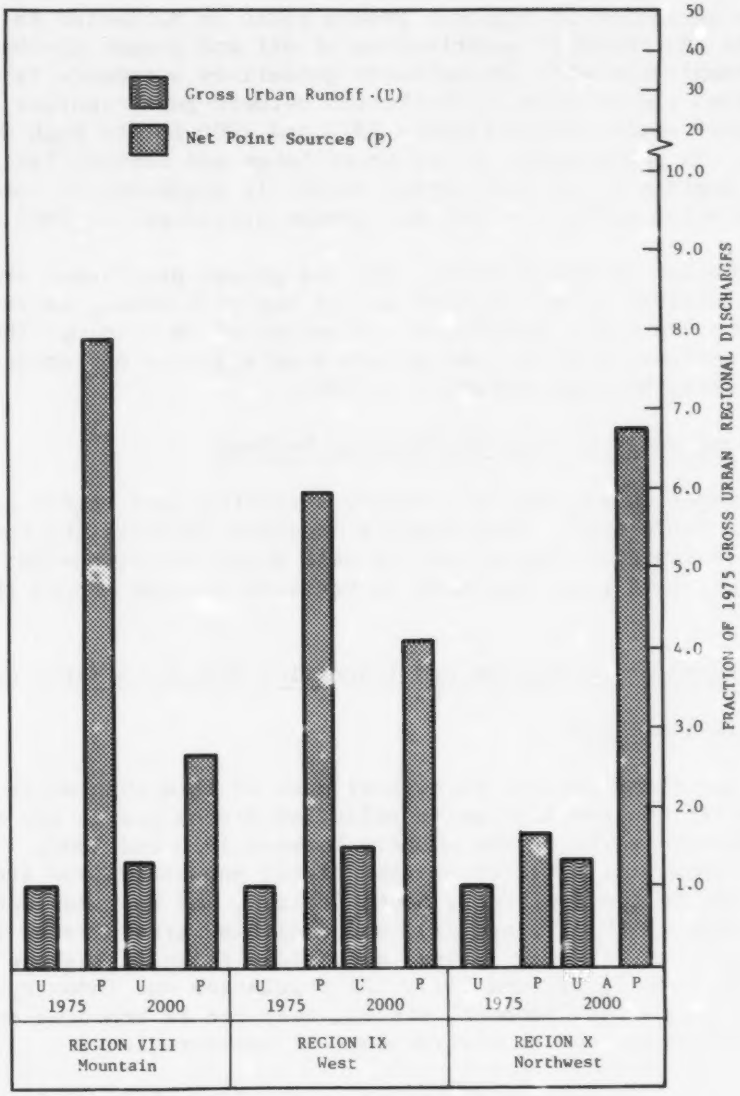

FIGURE 6-40 (CONCLUDED)
TRENDS IN REGIONAL DISCHARGES OF OIL AND GREASE BY POLLUTING SOURCE HIGH GROWTH SCENARIO 1975 AND 2000

This variation in regional growth rates is reflected in expected changes in the regional distribution of oil and grease discharges. If full compliance with EPA effluent guidelines standards is achieved by industry, the relative contribution between point sources and urban runoff would change between 1975 and 2000 in the High Growth Scenario. In particular, in the Great Lakes and Central Regions (Federal Regions V and VII), urban runoff is projected to contribute more than point sources to oil and grease discharges by 2000.

In the Low Growth Scenario, oil and grease discharges are projected to decline in all regions except Region X where, as in the High Growth Scenario, discharges are projected to triple. The regional distribution of oil and grease discharges is not projected to differ greatly between scenarios by 2000.

6.4.3 Major Water Quality Problems in Regions

The major water quality problems affecting each region are summarized in Table 6-42. This summary includes not only the point and non-point pollutants covered in the SEAS model but also other pollutants that have been discussed in Sections 6.2 and 6.3 in this chapter.

6.4.4 Impacts of Population and Industrial Change on Water Quality

Population Shifts

A major trend evident throughout most of this chapter is a pronounced shift in growth of water pollution discharges to the southern and western parts of the country between 1975 and 2000. This shift has been attributed to assumed higher population and economic growth rates in the Southeast, South Central, and West Regions (Federal Regions IV, VI, and IX), and declining growth rates in the New England, New York-New Jersey, and Middle Atlantic Regions (Federal Regions I, II, and III). As population and industry migrate toward the so-called "Sunbelt" states, they can be expected to have a substantial impact on the environments of these regions.

This trend in population growth in the "Sunbelt" and "Frostbelt" regions is shown in Table 6-43. For purposes of this analysis, the Sunbelt is defined as Federal Regions IV, VI, and IX, and the Frostbelt is defined as Federal Regions I, II, and III. Population in the Sunbelt is expected to increase from 82 million in 1975 to 110 million by 2000 in the High Growth Scenario. This 35 percent increase is in contrast to the 13 percent increase in population projected over the same period in Federal Regions I, II, and III.

TABLE 6-42
MAJOR WATER QUALITY PROBLEMS AFFECTING EACH FEDERAL REGION

Region		Point	Non-point
I	New England	Heavy industry discharges of toxics of major concern.	Urban runoff continues to be an important source of water problems. Sediment losses are of major concern as well.
		The pulp and paper industry contributes to problems with BOD discharges.	
II	New York/ New Jersey	Toxic pollutants, particularly cadmium, are expected to be the major water quality problem. The cadmium emanates primarily from the organic chemicals industry.	Pollutants from urban runoff are expected to be a problem because of densely populated areas.
			Construction activities are also expected to pose water quality problems.
III	Middle Atlantic	Primarily because of the predominance of coal-fired power plants, copper discharges are a major pollutant.	Water pollution problems associated with mining activities cause the most concern. The most serious is acid mine drainage.
IV	Southeast	Because of its expected population growth and industrial expansion, problems in all pollutants will increase.	Increased urbanization leads to urban runoff problems.
			Two-thirds of all miscellaneous pesticides in the water are in this region, due to tobacco-growing activities.

(continued)

TABLE 6-42
(CONTINUED)

Region	Point	Non-point
V Great Lakes	Population increasing and greater utilization of sewage treatment lead to high levels of BOD.	Agricultural runoff, especially of nitrogen and phosphorus, is a major problem.
	Coal mining and preparation are responsible for high levels of suspended solids.	Urban runoff (particularly combined sewer overflows) causes water quality problems as well.
	Coal-fired power plants create problems associated with copper discharges.	
VI South Central	The greatest population increase and industrial expansion is expected here, and so is the greatest increase in almost all major and toxic water pollutants.	Heavy metals, primrily from ore mining, are a particular hazard.
		Pollutants associated with urban runoff, such as BOD and suspended solids, are expected to be of greater importance because of rapid growth rates.
		Agricultural runoff from irrigated cropland is also of concern.
VII Central	The meat processing industry is the major polluter. Oil and grease and phenols are special problems.	Agricultural runoff is the primary pollution source. Nitrogen, phosphorus, and fungicides due to soybean and corn production are of particular concern.

(continued)

TABLE 6-42
(CONCLUDED)

Region	Point	Non-point
VIII Mountain	BOD and nitrogen will become greater problems because of population growth.	Heavy metals from mining and dissolved solids from irrigation return flows activities are expected to pose water quality problems.
	Increased coal mining and preparation activity is expected to increase discharges of dissolved solids and phenol.	
IX West	Increased refining activities of Alaskan oil make oil and grease pollutants a continuing problem.	Sediment and pesticides from silviculture are the major water quality problem.
X Northwest	Oil and grease discharges from the Alaskan pipeline are of major concern.	Almost half of the national discharge of fungicides is projected here, primarily from potato production.
	Discharges of dissolved solids are expected to increase because of growth in coal-fired and nuclear-generated electricity.	

TABLE 6-43
POPULATION GROWTH PROJECTIONS, SUNBELT AND FROSTBELT REGIONS
1975-2000

	1975		1985						2000					
			High Growth			Low Growth			High Growth			Low Growth		
Region	Population (Millions)	Percent of National Total	Population (Millions)	Percent of Increase	Percent of National Total	Population (Millions)	Percent of Increase	Percent of National Total	Population (Millions)	Percent of Increase	Percent of National Total	Population (Millions)	Percent of Increase	Percent of National Total
Sunbelt														
IV. Southeast	35	16	41	17	17	40	14	17	48	38	19	44	25	18
VI. South Central	22	10	25	14	11	24	11	11	30	35	11	27	21	11
IX. West	25	12	28	15	12	28	12	12	32	31	12	30	21	12
Total	82	38	94	15	40	92	12	40	110	135	42	100	23	41
Frostbelt														
I. New England	12	16	13	7	6	13	4	6	14	17	6	14	11	6
II. New York/New Jersey	25	12	26	3	11	26	1	11	27	8	11	27	5	11
III. Middle Atlantic	24	11	26	7	11	25	4	11	28	16	11	27	11	11
Total	62	29	65	5	28	64	3	28	70	13	27	67	9	27

Although notable population shifts toward the southern and southwestern states are already incorporated into SEAS projections, there is evidence to suggest that population growth rates in several Sunbelt states are sharply underestimated while those in several Frostbelt states are overstated. State population shares in SEAS are based upon 1977 interim revisions to the latest comprehensive regional economic and demographic forecast (OBERS) released by the Department of Commerce.[147] Although this forecast incorporates adjustments for overseas population and the 1970 census undercount, these estimates differ from more recent data in several ways. By 1975, five Sunbelt states--Louisiana, Mississippi, South Carolina, Arizona, and Texas--had already exceeded OBERS 1980 population projections, and one state, New Mexico, had already surpassed its 1990 projection.[148] With respect to northeastern states, interim revisions to OBERS projections forecast a population growth in New York State of 1.1 million people over the 1970 to 1980 period when, in fact, population had decreased by 300,000 as of 1977; Pennsylvania has lost 16,000 people over the same period in contrast to a projected increase of nearly 800,000.

Current SEAS projections indicate that population impacts on water quality in Sunbelt states would be most notable in higher loadings of fecal coliform bacteria, oxygen-demanding materials, phosphorus, and nitrogen from greater amounts of raw sewage processed by municipal treatment plants. A more pronounced migratory shift to Sunbelt states can only be expected to affect water quality more severely with respect to these pollutants. Since the southwestern area of the United States reported only 36 and 14 percent of its hydrological basins affected by oxygen depletion in 1977 from point and non-point sources respectively (Tables 6-2 and 6-23), a more marked Sunbelt shift would be likely to increase pollution in currently affected basins and to pollute a greater number of basins by 2000.

Further water quality impacts are anticipated from industrial growth in the Sunbelt, where industry is projected to expand more rapidly than in north central and northeastern states. However, the dimensions of these impacts are not well defined. The belief, often stated, that a great many firms are leaving the northeast for Sunbelt states is not borne out by a recent report from the Economic Development Administration.[149] This report attributes higher economic growth rates in the Sunbelt to new enterprises and expansion of existing firms rather than to industrial migration. Also, although economic development creates employment and other opportunities, it has negative effects, among which is water pollution. The severity of water quality problems associated with excessive suspended solids, oil and grease, heavy metals, pH, thermal pollution, and toxic chemicals is expected to depend on the degree to which economic development shifts to southern and southwestern states.

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[147] U.S. Department of Commerce, Bureau of Economic Analysis, Population, Personal Income, and Earnings by State: Projections to 2000, Washington, D.C., October 1977.

[148] U.S. House of Representatives, Select Committee on Population, Domestic Consequences of United States Population Change, Washington, D.C., December 1978.

Although the Sunbelt region is the most striking example, other areas of the country can also expect water quality problems because of population and industrial changes. Two examples are the Mountain and Northwest Regions (VIII and X). Here, water quality impacts can be attributed in part to another kind of population movement taking place in some sections of the United States--that of migration from highly urbanized to rural and small town areas.

From April 1970 to July 1975, nonmetropolitan population in the country increased at an average rate of 1.2 percent per annum compared with a metropolitan population growth rate of 0.8 percent per year. This is in contrast to the 1960 to 1970 population pattern which showed an annual growth rate of 0.4 percent for the nonmetropolitan population and 1.6 percent for the metropolitan.[150] The net urban-to-rural migration (1.8 million people over the 1970 to 1975 period), if it continues, is likely to have major implications in terms of water quality, particularly in the regions (e.g., Federal Regions VIII and X) that are now more rural in character and are expected to experience much of this anticipated migration.

One major implication of dispersion of population to more rural areas concerns on-site treatment of sewage. As population density decreases and distances to centralized treatment facilities increase, the septic tank becomes more attractive as a wastewater treatment alternative.[151] As a result, areas expected to receive urban-to-rural migrants can also be expected to treat greater quantities of sewage on-site than more urbanized regions. This tendency is not reflected particularly well in current SEAS projections.

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[149] U.S. Department of Commerce, Economic Development Administration, Documenting the "Decline" of the North, Washington, D.C., June 1978.

[150] Beale, D.L., "The Recent Shift of United States Population to Nonmetropolitan Areas, 1970-1975," International Regional Science Review, Vol. 2, 1977.

[151] Downing, P.B., The Economics of Urban Sewage Disposal, Frederick A. Praeger, Inc., New York, 1969.

Water quality problems from on-site treatment can be more serious than those in municipal treatment plants. Septic systems are considered to be significant sources of groundwater contamination and, in some cases, surface water pollution. Septic tank problems relate to seepage either into the local water table or into surface waterways. Serious problems occur when the soil on which septic systems depend for absorption is not capable of purifying septic tank effluent before it reaches the ground water. In such cases, water in the surrounding area can be contaminated.

Seepage from septic tanks contains large amounts of grit, grease, solids, organic material, and heavy metals. The constituents of special concern are fecal coliform bacteria, ammonia, and phosphorus. Septic systems are not considered very effective in removing nitrogen from waste in most deeply aerated soils; nitrate levels have been found to be as high as 40 milligrams per liter within 20 feet of such a system.[152] Phosphates are less a problem because they may be removed by absorption in fine calcareous soils.

Water quality problems in nonurbanized areas are not limited to disposal of sewage. Greater dispersion of the population may also increase the severity of problems associated with soil erosion and urban runoff. As indicated in Table 6-44, water pollution can be expected to increase as population densities decline. Urban sprawl increases the amount of soil erosion because of the greater land areas used for roadways and construction. Development on land less suitable for settlement, such as on steep slopes and flood plains, can also aggravate runoff problems. Greater quantities of pollutants from stormwater runoff can be expected as the population disperses; low density settlements can generate almost a third more stormwater by volume than high density planned settlements.

The urban/rural population movements can also indirectly affect water quality through their impacts on prime agricultural land. In 1977, U.S. cropland amounted to 400 million acres, of which 250 million were considered prime. Between 1967 and 1975, 17 million acres of cropland were converted to urban use; almost half was prime

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[152] Ziebell, W.A., and E. McCoy, The Effects of Effluents on Groundwater: Bacteriological Aspects, Paper presented at the Second National Conference on Onsite Disposal, National Sanitation Foundation, Ann Arbor, Michigan, 1975.

TABLE 6-44
COMMUNITY COST ANALYSIS WATER POLLUTION AND EROSION

	Community Development Pattern (10,000 Units					
	Planned Mix	Combination Mix	Sprawl Mix	Low Density Planned	Low Density Sprawl	High Density Planned
Sediments from Erosion						
Average annual volume during development period (tons per year)[b]	4,470	4,450	4,430	5,600	6,170	3,640
Pollutants from Storm Runoff						
Total volume of runoff (thousands of liters per year)[c]	7,786	7,809	7,836	8,512	9,177	7,141
Pollutants (kilograms per year)[d]						
BOD	181	182	183	198	214	166
COD	490	492	294	536	578	450
Nitrogen	21	21	21	23	25	19
Phosphate	5	6	6	7	7	6
Suspended Solids	7,786	7,809	7,837	8,511	9,176	7,141
FCB (Number x 10^{-6} per year)	9,343	9,343	9,404	10	11,012	8,370

[a] Fifty percent PUD, 50 percent sprawl.

[b] Volumes of sediment from erosion calculated using same assumptions as in analysis of neighborhood water pollution and erosion areas derived from community prototype land budgets. Average duration of construction activity assumed to be .5 year.

[c] Volumes of storm runoff calculated using same assumptions as in analysis of neighborhood water pollution and erosion. Areas derived from community prototype land budgets. Annual precipitation is assumed to be 40 inches.

[d] Pollutant quantities from stormwater runoff use same assumptions as in analysis of neighborhood water pollution and erosion.

SOURCE: Real Estate Research Corporation, The Costs of Sprawl, Washington, DC, April 4, 1974. Used with permission.

agricultural land. Nationally, losses of prime farmland are estimated to approach 1 million acres per year.[153]

Loss of cropland to urban uses can be expected to have a detrimental effect on water quality not only because of the negative impacts associated with conversion, but also because of loss of the beneficial functions of open land. Open lands, including farmlands, help maintain local water supplied by absorbing precipitation and transferring the water to groundwater systems. Open lands protect the hydrologic integrity of watersheds by controlling stormwater runoff and sediment damage, and protect aquifer recharge areas and serve as buffers for water supply and other natural areas.[154]

As prime cropland is converted to urban uses, more marginal land, such as pastureland and rangeland, is likely to be brought under cultivation. As of 1975, only 110 million acres of such lands were estimated to have high or medium potential for conversion to cropland. Of this amount, only about 35 million acres could be converted without significant conservation practices.[155] The remainder is susceptible to wind and water erosion that could create suspended and dissolved solids pollution problems unless proper conservation measures were applied.

Other environmental problems can result from bringing marginal lands into cultivation. For example, to increase productivity, marginal lands might be subjected to more intensive fertilizer and pesticide application that would severely degrade water quality in the locality. Such problems could become critical in more arid regions under conditions of low stream flow and competing requirements for water.

Trends in population movement and land use conversion are uncertain, but the environmental impacts of population and industrial movement are clear. Severe water quality degradation in surface and ground waters could occur unless industrial, municipal, and on-site sources of pollutants are adequately controlled. Even if these sources achieved reasonable control, agricultural runoff from more marginal croplands and urban runoff from highly dispersed settlement patterns could seriously affect water quality.

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[153] U.S. Department of Agriculture, Soil Conservation Service, Potential Cropland Study, Statistical Bulletin No. 578, Washington, D.C., 1977.

[154] Council on Environmental Quality, Environmental Quality--1977, U.S. Government Printing Office, Washington, D.C., December 1977.

[155] U.S. Department of Agriculture, Soil Conservation Service, Potential Cropland Study, Statistical Bulletin No.578, Washington, D.C., 1977.

Emerging Industries

Another matter of concern is industries that either do not exist or are insignificant at present but are expected to grow substantially in the future. These "emerging" industries need to be taken into account because they may impact the air and water environments in which they are situated.

An example of an emerging industry is the synthetic fuels industry, which is expected to experience tremendous growth over the next 25 years. While the degree of penetration of this industry into the U.S. economy is still uncertain, it is likely, given current legislation initiatives and interest, that SEAS projections used in this chapter are conservative. If so, water quality impacts associated with synthetic fuels development are probably understated by SEAS.

High transportation costs for shipping raw materials are expected to limit expansion of this industry to regions containing significant quantities of coal and oil shale--primarily the western areas having extensive low-sulfur coal and oil shale resources. Water pollution impacts can therefore be expected to be regional rather than national in scope.

The production of synthetic liquid fuels has two types of impacts on the environment: direct, from the operation and construction of the plant itself; and indirect, from the developments required to support the plant's operation (e.g., coal mining; shale extraction; community growth; and construction of reservoirs, pipelines, transmission lines, highways, and railroads, along with industrial expansion attracted to the area by the plant).

All synthetic fuel production technologies produce many pollutants in wastewaters. For example, high-Btu gasification plants generate dissolved solids, suspended solids, sulfur compounds, ammonia, light hydrocarbons, tars and oils, cyanides, sulfates, and trace elements;[156] water used for cooling is a potential source of chemical or thermal pollution; algecides used to treat cooling tower water could be toxic to aquatic life if released to surface waters. Assumed compliance with effluent limitations guidelines, which are currently being formulated by EPA, can be expected to lessen the impacts considerably, and actual discharges of pollutants from production are expected to affect hydrological basins only moderately. However, groundwater contamination through leachate from solid waste disposal areas could be serious unless disposal sites are adequately secured.

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[156] Energy Research and Development Administration, Alternative Fuels Demonstration Program, ERDA-1547, Washington, D.C., 1977.

Even if wastewaters from synthetic fuel production are adequately controlled, indirect water quality impacts from resources extraction, solid waste disposal, and population and economic growth can be expected, and could severely affect basins in which this development is taking place. Although some pollution problems, particularly those related to construction, will be temporary, others, such as those associated with solid waste disposal and final product transportation, could have lasting and potentially harmful effects upon the water environment.

Summary

Uncertainty about the nature of water pollution problems likely to be faced by the nation over the coming decades has been highlighted in this section by considering contingencies related to population shifts and emerging industries. Clearly, many water quality problems not now defined can be expected to emerge. Some issues that are presently recognized, such as carcinogens in treated drinking water or impacts of effluent limitations variances because of economic hardship, cannot be meaningfully addressed given our current state of knowledge. Despite these shortcomings, however, projections and other data analyzed in this chapter have indicated what we might expect our water quality problems to be over the 1975 to 2000 period. They have identified regions where specific pollution problems are likely to occur and the economic conditions that might moderate these problems. This information provides a basis for working toward the solution of water quality problems in the future.

CHAPTER 7
DRINKING WATER

HIGHLIGHTS OF CHAPTER 7

- By the year 2000, approximately 90 percent of the U.S. population will be supplied with drinking water from centralized drinking water systems. Many of these facilities will be small systems serving rural areas.

- Although EPA and most state governments are actively involved with programs designed to upgrade the quality of drinking water, many small supply systems are frequently in violation of EPA drinking water standards.

- Hazardous wastes and synthetic organic contaminants have been noted in many drinking water supply systems, both before and after treatment. Additional surveys are expected to reveal increasing numbers of systems contaminated by these pollutants.

- Chlorine used as a drinking water disinfectant may react with organic materials suspended in the raw water supply and form trihalomethanes.

- Recent studies have shown a correlation between the incidence of heart disease and geographic areas of the country which use either naturally occurring or treated "soft" water.

7.1 INTRODUCTION

National concern over the quality of drinking water has heightened primarily because of an increased public awareness of drinking water pollution by industrial contaminants, urban and rural runoff, and leachate from septic tanks. The effects of inorganic and microbiological water pollutants on public health have been known and treated for some time. Improved analytical techniques have recently been used to identify organic compounds and trace metals not previously detected in drinking water supplies; these compounds are not normally removed by standard drinking water treatment methods. Several recently discovered pollutants may be associated with health problems such as cancer. Results of recent studies suggest that the sources of these pollutants include industrial and agricultural activities as well as the home use and disposal of chemicals in homes.

7.1.1 Legislative Background and Current Programs

The discovery of asbestos fibers in the water supply system of Duluth, Minnesota, and of 66 organic chemicals in the New Orleans

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water supply in the early 1970s gave impetus to the passage of the Safe Drinking Water Act of 1974.[1] EPA and the states are currently implementing the Act[2] by establishing programs for the protection of the nation's drinking water. These programs included the preparation of drinking water standards for substances which may have or are known to have adverse public health effects. On December 24, 1975, EPA promulgated National Interim Primary Drinking Water Regulations establishing maximum permissible levels for a number of inorganic compounds, chlorinated hydrocarbons, turbidity, and microbiological contaminants in public drinking water.[3] EPA regulations were promulgated in February 1978, identifying procedures for individual states to be granted the responsibility for enforcing the regulations.

It is the intent of the Act that individual state governments assume primary roles in promulgating and enforcing regulations for maintaining high quality drinking water. A state can qualify for primary enforcement responsibilities if it:

- Adopts regulations that are at least equal to the Federal regulations in protecting public health.
- Adopts and implements adequate surveillance and enforcement procedures.
- Provides for variances or exemptions that meet Federal requirements.
- Provides a plan for supplying safe drinking water under emergency circumstances.
- Keeps records and provides reports keeping EPA fully informed of its activities.

Table 7-1 lists the states and territories that have been granted responsibility for primary enforcement of the Act, and indicates the date by which EPA expects the remaining states to qualify.

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[1] Council on Environmental Quality, The Seventh Annual Report of the Council on Environmental Quality, U.S. Government Printing Office, Washington, D.C., 1976, p.65.

[2] The Safe Drinking Water Act of 1974 (PL 93-523), and as amended in 1977 (PL 95-190).

[3] Personal Communication, James McDermott, U.S. Environmental Protection Agency, Office of Drinking Water, March 19, 1980.

TABLE 7-1
STATES QUALIFIED TO ENFORCE THE SAFE DRINKING WATER ACT

	Year of State's Acceptance			States Pending Acceptance	
Region	FY 77	FY 78	FY 79	FY 80	Post FY 80
Region I	Connecticut Maine Massachusetts	New Hampshire Rhode Island		Vermont	
Region II	New York		Virgin Islands	New Jersey Puerto Rico	
Region III	Virginia	Delaware Maryland West Virginia			Pennsylvania District of Columbia
Region IV	Alabama Georgia Kentucky South Carolina Tennessee Mississippi	Florida		North Carolina	
Region V	Minnesota	Michigan Wisconsin	Ohio Illinois		Indiana
Region VI	Arkansas Louisiana Oklahoma	New Mexico Texas			
Region VII	Nebraska Iowa	Kansas	Missouri		
Region VIII		Colorado Montana North Dakota		Utah	South Dakota Wyoming
Region IX	Hawaii	Nevada Arizona California Trust territories of the Pacific Guam		American Samoa	
Region X		Alaska Idaho Washington			Oregon

Source: U.S. Environmental Protection Agency, Status Report: State Primacy for Public Water Systems, Supervision Program, Office of Drinking Water Assessment, March 1979.

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The Act calls for both primary and secondary drinking water regulations. Primary regulations apply to contaminants which may have adverse human health effects. The maximum permissible level for these contaminants is based on the economic and technical feasibility of available treatment techniques.[4] Secondary regulations establish contaminant levels to protect public welfare. Under these regulations contaminants which may adversely affect the odor and/or appearance of drinking water or cause a substantial number of persons to discontinue use of the public water system are addressed.[5]

In addition, the Safe Drinking Water Act gave EPA's Administrator authority to regulate the injection of fluids into subsurface wells. The underground injection of industrial liquid waste materials was becoming an increasingly common practice. This was particularly true after the passage of the Federal Water Pollution Control Act, which restricted direct waste discharges. Since 50 percent of the nation's population now obtains their drinking water from ground water sources, protection of drinking water aquifers is of importance.

To prevent contamination of underground sources of drinking water, EPA's Underground Injection Control (UIC) Program was established. On April 20, 1979, and June 14, 1979, EPA proposed regulations to govern the UIC program and described specific requirements for injection facilities and monitoring.

Two additional EPA activities, closely related to drinking water quality, are the Surface Impoundment Assessment (SIA) Program and the Sole Source Aquifer (SSA) Program.

The SIA Program is designed to assist states in preparing inventories and initially assessing the impacts of surface impoundments used as liquid wasteholding pits, ponds, or lagoons. A majority of states have agreed to participate in the SIA Program. Most of the inventories have been completed, and a national report will be completed by mid-1980.

Under the SSA Program anyone may petition EPA to designate aquifers that serve as the sole or principal source of drinking water for a given area. No Federal financial assistance may be extended to any project in a designated area if the project may contaminate the sole source aquifer so as to create a significant hazard to public health.

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[4] Personal Communication, James McDermott, U.S. Environmental Protection Agency, Office of Drinking Water, March 19, 1980.
[5] Ibid.

7.1.2 Data Sources and Quality

Information used in the preparation of this chapter was obtained through a review of a number of reports and studies. The major data sources used include the following:

EPA Operating Year Guidance, 1980[6]

The Nation's Water Resources, 1978[7]

Drinking Water Supplies in Rural America, 1978[8]

"Disease Outbreaks Caused by Drinking Water," 1979[9]

To augment this information, persons in EPA's Office of Drinking Water at Headquarters and in the drinking water sections of each of the 10 Federal Regions were contacted to obtain information on current trends. Although these sources provide an adequate assessment of drinking water problems, they generally do not provide adequate information on contaminant trends. This is primarily because long-term data are not available, since most of the contaminants have only recently been identified as being of concern in drinking water.

7.1.3 Organization of Chapter

The remainder of this chapter provides a brief overview of the current condition and future outlook of drinking water resources in the United States. The next section describes sources of drinking water supplies, including surface and ground water. Section 7.3 provides an overview of the major drinking water contaminants. In the overview, the contaminants and their sources are identified, and generalized trends in research or regulatory programs which deal with the contaminants are presented. The discussion of implications identifies areas for future emphasis at national and regional levels.

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[6] U.S. Environmental Protection Agency, EPA Operating Year Guidance, Operating Year Guidance for Fiscal Year 1981, Washington, D.C., February 1980, pp. 16-18.

[7] U.S. Water Resources Council, The Nation's Water Resources: 1975-2000, Second National Water Assessment, Vol. I, Summary Report, U.S. Government Printing Office, Washington, D.C., 1978, pp. 7-15.

[8] National Demonstration Water Project, Drinking Water Supplies in Rural America, Washington, D.C., 1978.

[9] Craun, G.F., "Disease Outbreaks Caused by Drinking Water," Journal Water Pollution Federation, Vol. 51, 1979, pp. 1751-1760.

Section 7.4 provides an overview of domestic drinking water supply systems. The overview includes a discussion of centralized treatment systems as well as non-centralized rural systems serving individual households. The chapter concludes with a short regional analysis of the status of the EPA drinking water programs.

7.2 SOURCES OF DRINKING WATER

The sources of drinking water in the United States are primarily surface water from streams, lakes, and rivers, and ground water from underground aquifers. Systems for delivering this water range from simple wells, supplying the needs of a single household, to major municipal water treatment and distribution systems, supplying large metropolitan areas. The following paragraphs briefly discuss these drinking water sources of water. Chapter 8 provides related information on water resources more generally.

7.2.1 Surface Water Supply

Surface water is generally available for use as a freshwater drinking source from the time it strikes the ground as precipitation until it is discharged into the saline waters of an estuary or a desert "sink". It can be used as a source of drinking water only so long as it is not excessively contaminated by human activity or natural pollutants and can be economically treated. Approximately half the drinking water used in the United States comes from surface water sources, and an additional 15 percent from ground water sources that are closely dependent on surface water streamflow for replenishment.[10]

An assessment of the total surface supply of fresh water is presented in Table 7-2. The table lists the 21 Water Resource Regions of the Water Resources Council (see Figure 8-1, Chapter 8) and identifies the total available supply of surface water for all uses. It should be noted that these Water Resource Regions do not coincide with the EPA Federal Regions.

The quantity of available surface water varies both by season and by geographic region. These variations are driven by the rate of precipitation during a given year. For example, in 1961 and 1966, annual precipitation in the northeastern United States was extremely

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[10] U.S. Water Resources Council, The Nation's Water Resources: 1975-2000, Second National Water Assessment, Vol. I, Summary Report, U.S. Government Printing Office, Washington, D.C., 1978, pp. 7-15.

TABLE 7-2
U.S. FRESHWATER SURFACE SUPPLIES, BY WATER RESOURCE REGIONS OF THE WATER RESOURCES COUNCIL, 1975[a,b]

Region Number and Name	Drainage Areas (Thousands of Acres)	Mean Streamflow Discharge (Billion Gallons Per Day)
1. New England	44,162	78.2
2. Mid-Atlantic	66,139	79.2
3. South Atlantic-Gulf	173,630	228.0
4. Great Lakes	85,871	72.7
5. Ohio	102,436	178.0[d]
6. Tennessee	27,290	40.8[d]
7. Upper Mississippi	115,631	121.0[d]
8. Lower Mississippi	67,292	433.0
9. Souris-Red-Rainy	35,021	6.0
10. Missouri	327,133	44.1[d]
11. Arkansas-White-Red	156,463	62.6[d]
12. Texas-Gulf	113,726	28.3
13. Rio Grande	87,764	1.2
14. Upper Colorado	65,848	10.0[d]
15. Lower Colorado	99,103	1.6
16. Great Basin	89,181	2.6
17. Pacific Northwest	173,366	255.3
18. California	105,497	47.4
19. Alaska	375,304	905.0
20. Hawaii	4,126	6.7
21. Caribbean	2,283	4.9
Conterminous United States[c] (No. 1-18)	1,935,253	1,233.4
Total, all regions[c]	2,316,966	2,150.0

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[a] Preliminary data.

[b] See Figure 8-1, Chapter 8, for a map of the Water Resource Regions.

[c] Total discharge includes only those regions that are outflow points, that is, flowing out of the country, and does not include interior regions.

[d] Not included in total because these are inflows to other regions.

Sources: Drainage Area: U.S. Water Resources Council, The Nation's Water Resources: 1975-2000, Second National Water Assessment, Statistical Appendix, Volume A-1, Table 4, draft, April 1978. Streamflow: U.S. Water Resources Council, unpublished preliminary data.

low. This resulted in a drought, which adversely affected drinking water supplies in the Northeast Corridor. The effects of drought are particularly severe in those areas of the country which do not have adequate storage and distribution systems.

7.2.2 Ground Water Supply

Between 1900 and 1975, the use of ground water as a source of drinking water increased in the United States at an annual rate of approximately 3.8 percent. In 1975, ground water withdrawals represented over 40 percent of total freshwater withdrawal.[11] A significant portion of this increase can be attributed to the use of ground water for irrigation of croplands. It is estimated that more than 82 billion gallons per day (bgd) are presently withdrawn (Table 7-3). Of this amount, approximately 57 bgd are used for cropland irrigation purposes. This large withdrawal has resulted in conflicts between irrigation and drinking water supplies in a number of western states that depend on ground water as their major drinking water source.

Much more ground water than surface water is available in the United States. Most of the ground water withdrawn is continually replaced by runoff and seepage from rain and snow, but approximately 21 mgd are "mined", that is, withdrawn without replenishment (see Table 7-3). During periods of drought, streamflow is often supplied entirely by ground water sources. With the heavy demands place on ground water sources in some portions of the United States, the problems created by extensive ground water mining can be severe.

7.3 MAJOR DRINKING WATER CONTAMINANTS

Demands for potable drinking water sources have closely paralleled increases in population and development. Since the turn of the century, improvements in drinking water quality have been dramatic, largely because of increased awareness of the sources of drinking water contaminants and development of technologies for improving drinking water treatment systems.

Two major categories of drinking water contaminants are biological contaminants, which include pathogenic bacteria and viruses, and chemical contaminants, which include inorganic chemicals such as nitrates, phosphates, or trace metals, and organic chemicals such as chlorinated hydrocarbons or oil.

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[11] U.S. Water Resources Council, The Nation's Water Resources: 1975-2000, Second National Water Assessment, Vol. I, Summary Report, U.S. Government Printing Office, Washington, D.C., 1978, pp. 7-15.

TABLE 7-3
U.S. GROUNDWATER SUPPLIES, BY WATER RESOURCE REGIONS OF THE WATER RESOURCES COUNCIL, 1975[a]

Region Number and Name	Groundwater Withdrawals: Total Withdrawals (in million gallons per day)	Groundwater Withdrawals: Withdrawals in Excess of Recharge (in million gallons per day)
1. New England	635	0
2. Mid-Atlantic	2,661	32
3. South Atlantic-Gulf	5,449	339
4. Great Lakes	1,215	27
5. Ohio	1,843	0
6. Tennessee	271	0
7. Upper Mississippi	2,366	0
8. Lower Mississippi	4,883	412
9. Souris-Red-Rainy	86	0
10. Missouri	10,407	2,557
11. Arkansas-White-Red	8,846	5,457
12. Texas-Gulf	7,222	5,578
13. Rio Grande	2,335	657
14. Upper Colorado	126	0
15. Lower Colorado	5,008	2,415
16. Great Basin	1,424	591
17. Pacific Northwest	7,348	627
18. California	19,160	2,197
19. Alaska	44	0
20. Hawaii	790	0
21. Caribbean	254	13
Total United States, all regions	82,328	20,902

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[a] See Figure 8-1, Chapter 8, for a map of the Water Resource Regions.

Source: Adapted from U.S. Water Resources Council, The Nation's Water Resources: 1975-2000, Second National Water Assessment, Volume I, Summary Report, U.S. Government Printing Office, Washington, D.C., December 1978, p. 18.

The sources of these contaminants are varied. Some, such as nitrates, may naturally occur in high concentrations. However, most of them are usually introduced into drinking water supplies as a result of human activities. Landfills, liquid storage lagoons, and deep-well injection sites all represent potential sources of contaminants to ground water supplies. Point source discharges of industrial and municipal wastes and overland runoff from fertilized croplands are additional sources of surface drinking water contaminants. Both surface and ground waters can also be affected by spills of liquid or solid industrial materials.

The problems of drinking water contaminants, including the sources, trends, and implications of these contaminants in drinking water supplies are briefly discussed below. Contaminants are discussed in three groups: biological and inorganic, organic (including chlorinated hydrocarbons), and hazardous wastes (including trace metals and some contaminants from the first two groups). Trends in the discharge of industrial and municipal waste pollutants were discussed in detail in Chapter 6.

7.3.1 Biological and Inorganic Contaminants

Early drinking water treatment systems were designed to reduce biological contaminants in surface supplies of drinking water. Biological contaminants, which include pathogenic bacteria and viruses, entered these supplies when raw or partially treated sewage was dumped into surface waters. In these early systems, treatment consisted mainly of disinfection or filtration. As laboratory testing methods improved, inorganic pollutants such as nitrates and lead were identified and measured in drinking water supplies. Low concentrations of most of these inorganic materials occur naturally in both surface and groundwater; it is only when they are introduced in quantities large enough to cause harmful effects that they become contaminants.

The Safe Drinking Water Act required EPA to develop a list of drinking water regulations for water supply systems.[12] The list includes a number of biological and inorganic constituents which have the potential for contaminating drinking water, and recommends maximum limits for the concentrations of these constituents.

Biological and inorganic contaminant problems have been identified in most of the 10 Federal Regions. Surface water supplies frequently have bacterial concentrations and turbidity levels that exceed the standards. These often are the result of non-point as well as point sources of contaminants. It has been suggested that these high concentrations of bacteria are the result of poor water treatment plant operating procedures.

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[12] The Safe drinking Water Act of 1974 (PL 93-523), and as amended in 1977 (PL 95-190).

The pattern for inorganic contamination of drinking water supplies is rather different. Saltwater encroachment in ground water supplies has been noted in many coastal regions, especially in the eastern and Gulf areas. It has also occurred in the west where freshwater aquifers overlap with saline aquifers. In regions having extensive agricultural, increased levels of nitrates in ground water supplies have been noted as well as in areas that depend on septic tanks as a primary means of wastewater disposal. Finally, naturally occurring high concentrations of nitrate, fluoride, barium, and radium have been noted in various Federal Regions. The radium noted in the Southeast Region (Federal Region IV) has been attributed to locally occurring phosphate deposits.

Trends

The continued identification of naturally occurring inorganic contaminants in many drinking water supplies suggests the need for additional research to understand the potential health effects of increased exposure to these contaminants. As noted in EPA's draft, Drinking Water Research Strategy, 1979-1981:[13]

> Toxicological or associated epidemiological studies or both should be conducted under a strong quality assurance program for inorganics presently regulated (Pb, Ba, F, As, NO_3, and Se) and for compounds (U, Rn, Th, asbestos, Mo, Sb, Li, Sn, Na) that may be regulated in the future.

The microbiological contaminant problems identified in many of the small drinking water systems supply waters suggest the need for additional research to develop economical small disinfection processes. In addition, as the primary drinking water regulations are revised, it is anticipated that the quality of drinking water supplies will be lower than at present. This means that additional information on the risks of infectious disease and the prevalence of specific microorganisms is needed, and it places further demands on the technical assistance and laboratory aspects of the current drinking water program.[14]

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[13] U.S. EPA, Drinking Water Research Strategy, 1979-1981, Office of Research and Development/Office of Water and Waste Management, U.S. EPA, Washington, D.C., 1979, pp. 36-39.

[14] Ibid. pp. 57-59.

A recent survey of the raw water supply quality of 138 municipal drinking water systems indicated that a significant percentage of these source waters were violating EPA-recommended limits for selected biological and inorganic contaminants. The findings of this study are presented in Table 7-4. The data indicate that about 20 percent of the 138 source waters exceeded the recommended limits for bacterial concentration, 35 percent exceeded the recommended limits for manganese, 23 percent for cadmium, and 16 percent for iron.

Implications

While the survey data suggest that most municipal drinking water systems are in compliance with Federal recommendations, information on contaminant problems within the 10 Federal Regions indicates that scattered problems still exist in the control of biological and inorganic contaminants. The affected regions have recognized these problems and are placing more emphasis on identifying and implementing solutions.[15]

A problem closely related to inorganic contaminants in drinking water is the relationship of the hardness of drinking water to the occurrence of heart disease. Results of recent studies have shown a strong correlation between increased incidence of heart disease and geographic areas of the country which use either naturally occurring or treated "soft" drinking water.[16] Although these studies indicate a correlation, continued research is needed to corroborate these research findings with clinical and epidemiological investigations. Figures 7-1 and 7-2 are mapped overviews of the occurrence of water softness and incidence of cardiovascular diseases, nationwide.

Waterborne biological and inorganic contaminants have been known to cause various types of diseases ranging from simple infections to chemical burns. From 1971 to 1977, 192 outbreaks of waterborne disease affecting 36,757 persons were reported in the United States.[17] The majority of the outbreaks of disease occurred in

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[15] Personal Communication, John Egan, Drinking Water Section, Region III and other EPA Regional Officials, Washington D.C., April 1980.

[16] Council on Environmental Quality, The Eighth Annual Report of the Council on Environmental Quality, U.S. Government Printing Office, Washington, D.C., 1977, pp. 256-266.

[17] Craun, G.F., "Waterborne Disease, A Status Report Emphasizing Outbreaks in Groundwater Systems," Groundwater, Vol. 2, 1979, p. 183.

TABLE 7-4

SELECTED WATER QUALITY CONSTITUENT VIOLATIONS IN 138[a] MUNICIPAL SUPPLY SOURCES, 1955-1977

Water Quality Constituent	Recommended Limit	Number of Means Available[a]	Number in Violation	Percentage in Violation
Biological				
Fecal coliforms	2,000/100 ml[b]	66	16	24
Total coliforms	20,000/100 ml[b]	43	9	21
Biochemical oxygen demand	5.0 mg/l[c]	64	5	8
Dissolved oxygen[d]	5.0 mg/l[c]	91	1	1
Chemical[e]				
Arsenic	0.05 mg/l[e]	63	4	6
Barium	1.0 mg/l	38	0	0
Boron	0.750 mg/l[c]	40	0	0
Cadmium	0.01 mg/l	61	14	23
Chloride	250 mg/l	127	1	1
Chromium	0.05 mg/l	41	0	0
Copper	1.0 mg/l	68	1	2
Iron	0.3 mg/l	45	7	16
Lead	0.05 mg/l	60	6	10
Manganese	0.05 mg/l	40	14	35
pH (lower limit)[e]	5	110	1	1
pH (upper limit)	9	110	3	3
Silver	0.05 mg/l[c]	50	0	0
Sulfate	250 mg/l	111	1	1
Zinc	5.0 mg/l	62	0	0

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[a] Constituent coverage varies considerably among monitoring stations.

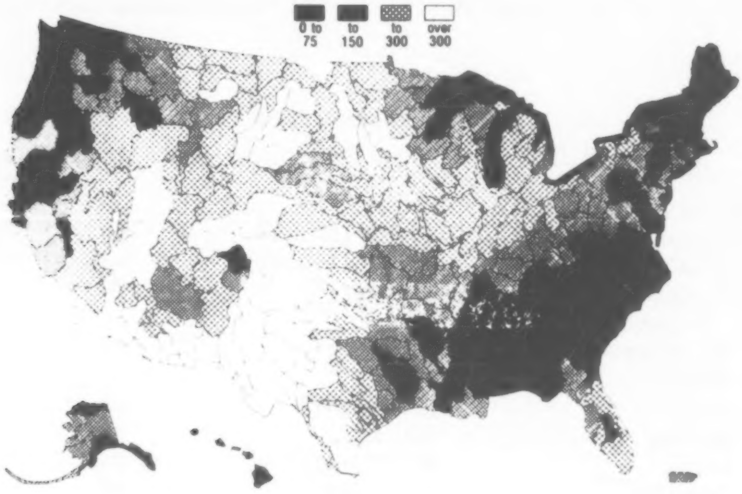
[b] Recommended limits as defined by National Academy of Sciences, Water Quality Criteria, 1972, No. 5501-00520, Government Printing Office, Washington, D.C., 1972.

[c] Arbitrary benchmark established by the Council on Environmental Quality.

[d] Values below these limits are considered in violation.

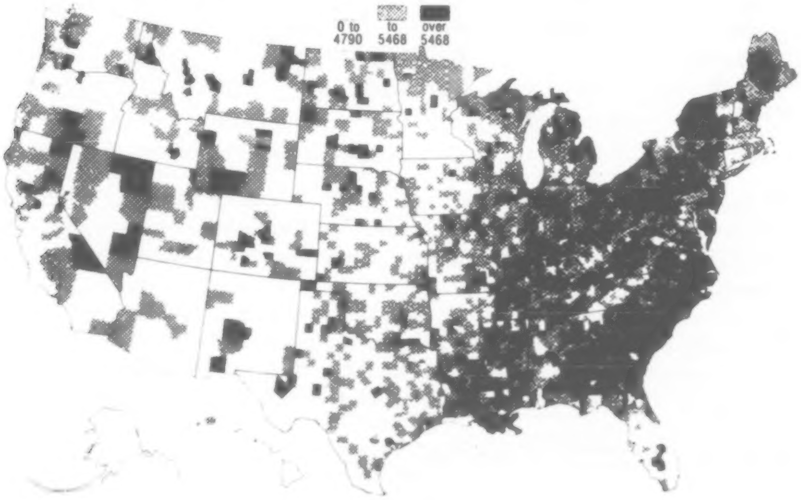
[e] Recommended limits as defined by U.S. Environmental Protection Agency, Quality Criteria for Water, EPA-44019-76-023, Washington, D.C., 1976.

Source: UPGRADE, based on EPA's STORET system data.


0 to 75
to 150
to 300
over 300

Source: UPGRADE, based on U.S. Geological Survey's National Stream Quality Accounting Network data.

FIGURE 7-1
U.S. WATER HARDNESS (MILLIGRAMS/LITER)
WATER YEAR 1975


0 to 4790
to 5468
over 5468

Source: UPGRADE, based on U.S. Department of Health, Education and Welfare's National Center for Health Statistics data.

FIGURE 7-2
CARDIOVASCULAR DISEASES, AGE-ADJUSTED MORTALITY
(MILLION POPULATION)
1968-1972

non-municipal water systems (70 percent). Approximately one-half of these outbreaks and illnesses resulted from the use of either untreated or improperly treated ground water.[18] The percentage of outbreaks and the incidence of illness for seven major categories of disease are presented in Table 7-5.

7.3.2 Organic Contaminants

Organic contaminants include both naturally occurring substances such as tar and oil, and synthetic compounds such as trichloroethylene or Kepone. Advanced laboratory techniques have been used to identify and quantify numerous synthetic organic compounds in drinking water supply systems. Many of these compounds were identified in waters already treated by filtration and chlorination.[19]

Trends

In 1974, a study of the water supplies of 80 cities identified the presence of trace organics in the drinking water supplies at 113 locations.[20] The identified compounds were chiefly trihalomethanes. By 1978, nearly 700 organic compounds had been identified in U.S. drinking water supplies. With the continued increase in the use of organic chemical compounds in industry, homes, and agriculture, it is anticipated that larger numbers of these organic contaminants will find their way into the nation's drinking water supplies. In 1979, regulations for the control of trihalomethanes were promulgated by EPA.

Synthetic organic contaminants have been identified in both surface water and ground water drinking supplies in most of the EPA regions. Trichloroethylene has been the most commonly identified contaminant in this category, but contamination from Kepone in James River at Hopewell, Virginia, has probably received the greatest public attention. Another compound identified in agricultural areas has been dibromochloropropane (DBCP), a pesticide.

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[18] Craun, G.F., "Disease Outbreaks Caused by Drinking Water," Journal Water Pollution Federation, Vol. 51, 1979, pp. 1751-1760.

[19] Council on Environmental Quality, The Eighth Annual Report of the Council on Environmental Quality, U.S. Government Printing Office, Washington, D.C., 1977, pp. 256-266.

[20] Ibid.

TABLE 7-5
ETIOLOGY OF WATERBORNE DISEASE OUTBREAKS
IN THE UNITED STATES, 1971-1977

Disease	Outbreaks (Percent)
Acute gastrointestinal illness	57
Chemical poisoning	12
Giardiasis	10
Shigellosis	9
Hepatitis A	8
Salmonellosis	2
Typhoid	2
Enterotoxigenic *E. coli*	<1
	100

Source: Adapted from Craun, G.F. "Disease Outbreaks Caused by Drinking Water," *Journal Water Pollution Control Federation*, Vol. 51, June 1979, pp. 1751-1760.

In some regions, concentrations of synthetic organics have been high enough to warrant closing of small drinking water systems. Discussions with persons in EPA Regional Offices suggest a number of sources of these synthetic organic contaminants. While many of these are related to individual spills or waste disposal surface impoundments, many may also be attributed to the leaching of improperly disposed cleaning solvents in landfills or septic systems.

Implications

Recent studies have suggested that many of these organic compounds, particularly synthetics, are health concerns.[21] Because of this potential for detrimental health effects, additional studies are needed to identify the sources of the contaminants, their occurrence in drinking water supplies, and their effects on public health. To meet these needs, EPA has implemented a number of projects at both the Federal and state levels. One such program is being used to identify the sources of these organic pollutants, as well as inorganic contaminants. This is the Surface Impoundment Assessment Program described earlier. The first phase of the SIA Program is currently under way in most states. This phase is designed to locate surface impoundments of waste materials. At present, approximately 173,000 such impoundments have been identified.

A problem receiving considerable attention in the past few years is the potential for the formation of chlorinated hydrocarbons when chlorine is used as the primary disinfectant in water treatment. Studies have shown that many chlorinated hydrocarbons are carcinogenic or otherwise hazardous to public health. While it is important to limit human contact with these potential carcinogens, it is equally important to protect the public health from waterborne bacteria and viruses. Two methods are being used to resolve this conflict. First, studies are being conducted to identify the formation processes for these chlorinated hydrocarbons and their potential effects. And second, drinking water treatment technologies utilizing other methods of primary disinfection, such as ozonation, are being developed.

7.3.3 Hazardous Wastes

Hazardous wastes include inorganic and organic waste materials that have been identified as hazards to health or the environment. These materials are discussed in more detail in Chapter 10, "Solid and Hazardous Wastes"; the following discussion identifies their implications for drinking water quality. Regulations are currently being prepared for the following list of hazardous materials:[22]

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[21] Craun, G.F., "Disease Outbreaks Caused by Drinking Water," Journal Water Pollution Federation, Vol. 51, 1979, p. 1751-1760.

- Acrylonitrile
- Arsenic
- Chloroform and chlorinated solvents
  - Trichloroethylene
  - Perchloroethylene
  - Methylchloroform
- Chlorofluorocarbons
- Chromates
- Coke-oven emissions
- Dibromochloropropane
- Diethylstilbestrol
- Ethylene dibromide
- Ethylene oxide and residues
- Lead
- Mercury and mercury compounds
- Nitrosamines
- Ozone
- PBBs
- PCBs
- Sulfur dioxide
- Vinyl chloride; polyvinyl chloride

These waste materials may enter surface water and ground water drinking supplies either directly (through accidental spills or the improper treating and disposal of industrial wastes); or indirectly (through leaching of these materials from abandoned holding ponds, lagoons, or landfills). Ground water contaminants can also result from underground migration of hazardous wastes that were disposed of through subsurface injection techniques.

Many of these hazardous wastes have been identified as carcinogens while others have been related to incidences of genetic mutation and chemical poisonings.[23] Incidents of drinking water contamination from hazardous wastes have been identified in almost all states. These problems are generally localized and affect a relatively small segment of the population.

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[22] U.S. Environmental Protection Agency, Third Report of the TSCA Interagency Testing Committee to the Administrator, January 1979.

[23] U.S. Water Resources Council, The Nation's Water Resources: 1975-2000, Second National Water Assessment, Vol. I, Summary Report, U.S. Government Printing Office, Washington, D.C., 1978, p. 21.

Trends

With the development and application of advanced laboratory techniques, EPA researchers have been able to identify and quantify the occurrence of hazardous waste materials in a number of drinking water supplies. Localized occurrences of these materials have recently been noted throughout the country. Such incidents as the discovery of hazardous materials at the Love Canal waste disposal site near Niagara Falls, New York; the increased concentration of phenols in the aquifer which supplies drinking water for the Minneapolis, Minnesota area (attributed to an abandoned creosote plant); and the disposal of arsenic byproducts in a landfill in Iowa provide good examples of the magnitude of the hazardous waste disposal problem.

The total number of drinking water supplies adversely affected by hazardous wastes is largely unknown. This lack of information may be due to limited monitoring capabilities at many of the small drinking water treatment systems. As additional surveys are undertaken, the number of drinking water supplies found to be affected by hazardous wastes is expected to increase.

Implications

Hazardous waste materials have been identified as a major problem area in most of the Federal Regions. However, the greatest concern about these wastes has been expressed in those regions that have been heavily industrialized, particularly in the northeast. To deal effectively with the hazardous waste problem, EPA has recognized the need to identify further the sources of these materials and their impacts. The SIA Program discussed in Sections 7.1.1 and 7.3.2 has identified an estimated 173,000 surface impoundments to date. However, further surveys and assessments of the impacts associated with these waste disposal sites are needed.

Preventive programs have also been instituted to protect ground water sources from contamination by hazardous wastes. The Safe Drinking Water Act requires the Administrator of EPA to implement, where needed, programs to control the subsurface injection of waste materials for disposal. Subsurface injection is used to dispose of waste materials by placing them in underground rock formations that do not contain useful ground water supplies and are isolated from freshwater resources. In response to the Act, EPA will soon promulgate regulations for the Underground Injection Control program as previously discussed.

7.4 DOMESTIC WATER SUPPLY SYSTEMS

7.4.1 Domestic Water Supply, Use, and Consumption

A Water Resources Council study suggests that the national average per capita rate of water use for domestic purposes is about 87 gallons per day (gpd). The rate of consumption of this water, however, is lower than the rate of usage.[24] The per capita rate of water use averages 107 gpd for central water supply systems and about 66 gpd for non-central, private, rural systems.[25] Based primarily on projected population increases, it is estimated that by the year 2000, domestic use of water will increase by about 8 billion gpd and the consumption of domestic water will increase by 2 billion gpd (Table 7-6).

7.4.2 Central Water Supply Systems

Trends

While local residents in some rural areas of the United States, depend on individual wells as a source of drinking water, the majority of the population uses central water supply systems. These may either be large systems, supplying the needs of major cities, or small community systems. EPA has been estimated that these systems currently provide the domestic water supply for 179 million people or roughly 87 percent of the national population.[26] The Water Resources Council has projected that by the year 2000 approximately 242 million people, or about 90 percent of the population, will be served by centralized systems. This increase can be attributed to projections of greater population growth within the urban areas presently served by central water systems, as well as to the continuing development and extension of central water systems to rural areas.

Water for central supply systems comes from either surface water or ground water sources. In general, large systems depend on surface water supplies, whereas smaller systems often rely on ground water supplies. The systems generally provide some form of treatment prior to distribution of the water. This ranges from simple disinfection,

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[24] Consumption refers to that portion of the total water used that is not returned to the source.

[25] U.S. Water Resources Council, The Nation's Water Resources: 1975-2000, Second National Water Assessment, Vol. I, Summary Report, U.S. Government Printing Office, Washington, D.C., 1978, pp. 7-15.

[26] Ibid.

TABLE 7-6
FRESHWATER WITHDRAWALS AND CONSUMPTION[a]
(AVERAGE YEAR, MILLION GALLONS PER DAY)

Water Resource Region	Withdrawals			Consumption		
	1975	1985	2000	1975	1985	2000
New England	1,483	1,616	1,798	212	231	254
Mid-Atlantic	4,604	5,193	5,994	796	891	1,010
South Atlantic-Gulf	2,841	3,433	4,255	998	1,217	1,506
Great Lakes	4,277	4,705	5,283	589	642	703
Ohio	2,337	2,597	2,914	411	456	498
Tennessee	353	421	499	70	81	90
Upper Mississippi	1,965	2,161	2,411	345	369	398
Lower Mississippi	805	880	960	343	370	398
Souris-Red-Rainy	68	71	70	31	31	31
Missouri	1,246	1,351	1,497	331	352	381
Arkansas-White-Red	945	1,028	1,132	348	377	409
Texas-Gulf	1,490	1,697	1,921	507	570	659
Rio Grande	327	352	380	169	182	196
Upper Colorado	80	86	94	28	31	33
Lower Colorado	498	612	772	234	288	364
Great Basins	378	444	530	148	170	201
Pacific Northwest	1,078	1,145	1,264	265	276	298
California	3,388	3,809	4,360	1,434	1,610	1,839
Alaska	91	114	147	7	10	12
Hawaii	177	209	256	55	64	78
Caribbean	355	428	514	58	72	88
Total Regions 1-18	28,163	31,601	36,134	7,259	8,144	9,268
Total Regions 1-21	28,786	32,352	37,051	7,379	8,290	9,446

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[a] Includes municipal, rural, domestic, and commercial water use.

Source: U.S. Water Resources Council, The Nation's Water Resources: 1975-2000, Second National Water Assessment, Vol. I, Summary Report, U.S. Government Printing Office, Washington, D.C., April 1978.

often with chlorine at smaller facilities, to complex filtration, aeration, and disinfection processes at larger facilities.

Most of the contaminant problems discussed in Section 7.3.1 (see Table 7-4) have been known and treated for a number of years. However, specific treatment processes for the more recently identified pollutants, such as synthetic organics and hazardous waste materials, may not always be readily available. Further, many of the small, older treatment facilities were not designed to provide the complex and often costly level of treatment required for control of these pollutants.

To maintain the quality of the water distributed by the central systems, EPA has prepared a series of regulations requiring the facility operators to monitor water quality at regular intervals. These regulations apply to central water supply systems that serve 25 or more customers. Samples taken for monitoring are to be analyzed at laboratories that either have interim approval from EPA or are certified by a state. If the samples are found to contain criteria contaminants in excess of the established levels, a public notice describing the violation is to be prepared, and proper actions are to be taken by the operator to correct the violation. The large number of small central water supply systems has made it difficult for EPA to enforce these regulations, particularly the requirement for public notification. In addition, many laboratories associated with the smaller systems are not equipped to identify or quantify synthetic organics and other hazardous wastes within the small systems.

Implications

Because of the trend toward use of smaller central drinking water treatment systems, particularly in rural areas, and the limited treatment capabilities at many of these small systems, EPA is developing a series of alternative low-cost treatment technologies. Much of this development will be based on adapting large treatment facility technologies to the needs of small treatment systems. The applications of these technologies could significantly raise the quality of the nation's drinking water.

In adapting these processes, EPA is attempting to keep the technology simple so that extensive operator training will not be required. The Agency is also attempting to keep the cost of these technologies low, so that their application will not place too great an economic burden on local communities. Primary emphasis is being placed on the development of treatment technologies to control nitrates, arsenic, fluorides, and selenium.[27]

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[27] U.S. Water Resources Council, The Nation's Water Resources: 1975-2000, Second National Water Assessment, Vol. I, Summary Report, U.S. Government Printing Office, Washington, D.C., 1978, pp. 7-15.

To reduce potential health risks associated with the use of chlorine as a disinfectant, EPA is directing research efforts to the development of alternative disinfection processes.

7.4.3 Non-Central Rural Water Supply Systems

Trends

The Water Resources Council has estimated that 33 million people, about 16 percent of the U.S. population currently obtain their water supplies from non-central water supply systems.[28] The majority of these systems, which consist mainly of single-family wells, are located in rural areas. The Council has estimated that an additional 4 million people in the United States are not served by a piped water supply system but must carry their water.

Projections indicate that the number of people using non-central water supply systems will decrease to 26 million, roughly 10 percent of the population, by the year 2000.[29] This will occur as a result of both population, shifts from rural to urban areas and expansion and development of centralized water systems in rural areas.

Implications

Since little information was available in 1974 on the quality, quantity, and availability of rural drinking water supplies, the Safe Drinking Water Act directed the EPA Administrator to enter into agreements with public or private entities to conduct a survey of rural drinking water.[30] This survey is to assess the condition of the nation's rural drinking water. A background document prepared by the National Demonstration Water Project in 1978, drew the following conclusions:[31]

1. A large segment of rural America lacks satisfactory domestic water supplies.
2. This problem occurs more frequently in sparsely populated areas.

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[28] U.S. Water Resources Council, The Nation's Water Resources: 1975-2000, Second National Water Assessment, Vol. I, Summary Report, U.S. Government Printing Office, Washington, D.C., 1978, p. 21.

[29] Ibid.

[30] The Safe Drinking Water Act of 1974 (PL 93-523), and as amended in 1977 (PL 95-190).

[31] National Demonstration Water Project, Drinking Water Supplies in Rural America, Washington, D.C., 1978.

3. The problem is more prevalent in non-farm rather than farm areas.
4. Satisfactory domestic water supplies are less prevalent in poorer areas.
5. The development of water supply systems in these areas often places an economic burden on the local population.

This report also suggested that small, private water supply companies be required to upgrade their systems as are public water utilities. However, the small companies do not have access to public funding for assistance. If these companies were unable to meet the requirements and were forced to close down, a gap in supply would be created.

An additional problem area noted by the National Demonstration Water Project Report is the lack of coordination between both public and private planning activities and funding and regulatory activities at all levels of government.[32] Funding and regulatory activities also are not coordinated. For example, while EPA is required to set standards the Agency has neither authority nor grant funds to assist with system and treatment improvements.

A final problem is the lack of an adequate outreach program by Federal, state, and local governments to give rural communities information on obtaining funds that have been set aside to assist with rural water supply programs.

7.5 DRINKING WATER ISSUES

The majority of the contaminant and supply problems discussed in this chapter are long-term problems. Their solutions are not simple and will often require considerable resource commitments. The amount of emphasis placed on these problems, at both the regional and national levels, appears to be a function of changes in public perception and awareness of the problems. The following comments present a brief overview of the major drinking water problems, issues, and trends as perceived by EPA at the national and regional levels.

7.5.1 National Office of Drinking Water

During 1979, the national emphasis has generally been centered on programs related to the control of organic pollutants. Treatment plant technologies and quality assurance of analytical methods are being given high priority by EPA. Other programs include dealing with problems related to health effects, development of better analytical methods, and groundwater research.

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[32] National Demonstration Water Project, Drinking Water Supplies in Rural America, Washington, D.C., 1978.

All ten Federal Regions are faced with the problem of the compliance of small community drinking water systems with the drinking water standards. EPA is starting a national effort to improve the drinking water quality of these small systems. This is to be a coordinated effort involving the Federal, state, and local governments through scientific research and development, technical assistance, enforcement actions and educational programs.

7.5.2 Regional

New England Region (Federal Region I)

Approximately 80 to 85 percent of the drinking water systems in Federal Region I obtain their water supply from groundwater sources. Contamination of these groundwater systems by synthetic organics, particularly trichloroethylene, has been identified as a major concern. This contaminant has caused a number of drinking water supply systems to be closed. It has been suggested that the probable source of the trichloroethylene is the disposal of cleaning fluids in septic systems. Additional problems of lesser concern include bacterial and turbidity contamination of surface water supplies. Saltwater encroachment has been noted in coastal areas, particularly Cape Cod. It is expected that future emphasis in the Region will be on dealing with synthetic organic pollutants and hazardous wastes. Alternative treatment technologies for dealing with the bacteria and turbidity problems, particularly in small systems, will also be explored.

The corrosive actions of certain natural waters on the pipes used for distribution are also a problem specific to Federal Region I. Contaminants leached by this action have included lead, cadmium and asbestos.

New York-New Jersey Region (Federal Region II)

Within Federal Region II, approximately 40 to 50 percent of the community drinking water systems utilize ground water as a source of supply. One sole source aquifer has been designated in the Region. The Surface Impoundment Assessment program has identified numerous sites in the heavily industrialized areas of New York and New Jersey.

Hazardous wastes have been identified as a major concern in the Region. Synthetic organics, entering groundwater sources from the leaching of chemical solvents disposed of in cesspools and septic tanks, have been noted. Turbidity in surface water supply systems and saltwater encroachment in coastal areas have also been noted.

Future emphasis in the Region is expected to include efforts to protect groundwater sources through the development of state strategies for dealing with synthetic organics. It is anticipated that additional technical assistance will be provided to the states to improve the operation of public water supply systems.

The Virgin Islands and Puerto Rico are also included in Federal Region II. While these islands do not have major drinking water quality problems, traditional problems such as bacterial and turbidity contamination have been noted in some water supply systems.

Middle Atlantic Region (Federal Region III)

Major contaminant problems in Federal Region III include synthetic organic compounds identified in both ground and surface waters. The sources of these contaminants include abandoned landfills, accidental spills, and septic tanks. One synthetic organic problem, trichloroethylene, found in the drinking water of Smyrna, Delaware, is being corrected through aeration of the water prior to distribution. Areas of future emphasis in the Region include providing additional technical assistance to state and local governments in upgrading treatment facilities, providing assistance in the preparation of underground injection control programs, and increasing public awareness of drinking water programs.

Federal Region III is currently implementing the Safe Drinking Water Act in the State of Pennsylvania. The state has indicated a desire to take over this program by 1982 and is currently investigating mechanisms to do so.

Southeast Region (Federal Region IV)

Within Federal Region IV, 92 percent of community drinking water systems use ground water as a source of supply. This source however, supplies only 50 percent of the population. This is a result of the use of surface water supplies in the metropolitan areas.

Drinking water quality in the Region has been good in past years. However, with increasing development, water quality problems may arise; increasing numbers of synthetic organic contaminants have been identified in drinking water supplies which had been considered pure. The sources of these synthetic organic compounds include industrial dumpsites, landfills, and possibly, injection wells. Other quality problems include high concentrations of naturally occurring radium from phosphate deposits, fluoride, barium, and increased levels of nitrate in agricultural areas.

Great Lakes Region (Federal Region V)

About 50 percent of the population in Federal Region V receives its drinking water from underground sources. In general, the large cities in the Region receive their supply from surface waters. Nitrates, fluorides, and trace metals have been identified as major concerns in the Region. Synthetic organics, primarily trichloroethylene, have also been identified in ground water. Sources of these contaminants include the leaching of cleaning solvents from septic systems. Phenols from an abandoned creosote factory near Minneapolis have been identified in the proposed water supply for a new development. Benzene has also been noted in the drinking water at a manufacturing plant in Indiana; industrial dumping is suspected as the source of the benzene.

In Federal Region V, future emphasis will be placed on developing a stronger technical program to assist state and local governments in dealing with synthetic organic pollutants.

South Central Region (Federal Region VI)

Contaminant problems in Federal Region VI are mostly related to traditional problems such as bacteria, fluorides, and nitrates. Bacterial problems have occurred mainly as a result of poor operating procedures at a few of the surface water treatment facilities. Naturally occurring fluoride and nitrate contaminants have exceeded recommended federal levels in portions of the Region. Future areas of emphasis in the South Central Region include assisting state and local governments with development of monitoring capabilities and treatment programs for dealing with synthetic organics. The implementation of the Underground Injection Control program will have a major impact in this Region because of the extensive oil and gas related activities and their use of injection techniques for waste disposal. EPA will be assisting the states in the South Central Region in the overall development of an injection control program and particularly in helping them to prepare the required permitting programs.

Central Region (Federal Region VII)

Contaminants in Federal Region VII at present include increased levels of nitrates and selenium. Synthetic organics have also been identified in the Region. Future emphasis in the Region will be on providing technical assistance to state and local governments in developing better programs for monitoring and treating synthetic organics.

Mountain Region (Federal Region VIII)

Control of underground injection of waste materials is an important issue in Federal Region VIII because of the practice of "solution mining" for the mining of uranium. This involves the injection of liquid materials into uranium ore deposits, dissolving the ores, and removal through withdrawal of the liquids.

Contaminant problems in this Region include traditional problems of increased bacteria and nitrate levels. Bacterial contaminants appear to result from agricultural runoff, septic tank leachates, and improperly treated surface water supplies. Nitrate contamination has been attributed to natural causes as well as to the leaching and runoff of fertilizers. High concentrations of naturally occurring fluoride have been identified in areas of North Dakota and South Dakota. In addition, some groundwaters in the region have been noted as having naturally high levels of uranium. Future emphasis in the Region will be on establishment of better monitoring programs and compliance schedules for inorganic, biological, and organic pollutants. Technical assistance will be provided to state and local governments in preparing programs to improve their drinking water quality.

West Region (Federal Region IX)

Contamination problems in Federal Region IX include bacteria in surface water supplies, nitrates (attributed to agricultural fertilizers), arsenic, and selenium in both ground and surface waters. Salinity has also been noted in groundwater supplies in Arizona. Synthetic organic contaminants have been reported in Arizona and California. These include dibromochloropropane, a pesticide which has been found in drinking water supplies in the agricultural regions of California.

Future EPA emphasis in Federal Region IX will be directed toward establishing programs to assist in the operation of small water treatment systems. In addition, EPA will concentrate its efforts in studies of specific contaminants such as dibromochloropropane, copper mine leachates, arsenic, and fluoride. EPA is also implementing the Safe Drinking Water Act in Indian Lands which are not controlled by the state's programs.

Northwest Region (Federal Region X)

Turbidity is a major contaminant problem in Federal Region X, because of the large number of unfiltered water supply systems. Organic and synthetic organic contaminants do not appear to be problems however, present monitoring techniques generally are not capable of detecting these contaminants. It is anticipated that synthetic organics will not be an issue, since the majority of watersheds supplying the Northwest Region are pristine.

Future emphasis in Federal Region X will be directed toward completion of Underground Injection Control Programs and development of better monitoring and compliance programs for small community systems.

CHAPTER 8
WATER RESOURCES

HIGHLIGHTS OF CHAPTER 8

- Based on data assembled by the U.S. Water Resources Council as reported in its Second National Water Assessment, the United States, when viewed nationally, has ample supplies of water. However, the uneven distribution of precipitation and competition for limited water supplies is causing, and will continue to cause, severe water problems in some parts of the nation.

- The use of ground water has been increasing gradually. Substantial ground water overdraft is occurring in some parts of the nation. Severe water quality and contamination problems are menacing some ground water systems.

- Agriculture is the dominant water use for both withdrawals and consumption. Improved irrigation efficiency could reduce withdrawals greatly.

- Especially in the west, energy development will compete with other water uses.

- A combination of high economic cost, technological uncertainty, and environmental considerations makes it unlikely that the total supply of water will increase substantially in the short term. Included in this category are desalination, weather modification, and additional storage capacity.

8.1 INTRODUCTION

8.1.1 Problem Identification

The effects of water resources planning and management policies are pervasive. Environment, food and fiber production, energy, regional economic development--even the U.S. international balance of trade--are all affected, either directly or indirectly, by water resources management.

Water resource issues have traditionally been treated as dichotomous--for example, water versus land, water quality versus water quantity, surface water versus ground water, point versus nonpoint sources of pollution, and water supply versus water demand. These classifications have helped to guide and structure discussions of water resource issues and problems, but they also have contributed

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to misconceptions and misunderstandings. Furthermore, the institutions for managing water resources mirror these dichotomies and therefore, water resource management is characterized by institutional fragmentation and decentralization. For example, within the Federal government, 26 agencies in 10 executive departments, plus 10 independent agencies and commissions, participate in water resource management. Each has a restricted disciplinary focus and a limited mission, often addressing narrow and specific aspects of the nation's water resources system.

As a result, there might be too much or too little management; it might be exercised in the wrong place, at the wrong time, or in the wrong way to serve the many demands. These combined inadequacies--plus such difficulties as water shortages, water pollution, floods and degradation of ground water systems--largely constitute "the water problem."

8.1.2 Legal Framework

In the United States, complex, nonuniform bodies of Federal and state water laws have evolved. For example, in connection with questions of water quality, Federal laws have been superimposed on the water laws of the 50 states. In the area of water availability, state laws prevail in general, eclipsed by the Federal government in cases of Federal or Indian reserved rights. Water rights and laws reflect a situation marked by significant conflict and uncertainty. Legal challenges abound and indicate that the validity of the existing legal framework remains in question.

State Laws: Surface Water

Two major doctrines--prior appropriation and riparian water rights--have been commonly adopted in the western and eastern states, respectively.[1]

Prior Appropriation. The Prior Appropriation doctrine, characteristic of the western states, rests on the maxim "first in time, first in right." The first landowner to establish a right to divert water is the last person to be cut off in time of shortage. The basic tenets of this system are that a water right can be acquired only by diverting the water from the watercourse and applying it to beneficial use; and that, in accordance with the date of acquisition, an earlier acquired water right in excess of the need to satisfy existing rights is viewed as unappropriated water available for appropriation by diversion and application of the water to a beneficial use.

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[1] National Water Commission, Water Policies for the Future, U.S. Government Printing Office, Washington, D.C., 1973. Also, Zink, A.R., "Water Availability in Western United States," Synthetic Liquid Fuels Development: Assessment of Critical Factors, Vol. II - Analysis, ERDA 78-129/2, U.S. Government Printing Office, Washington, D.C., 1976. Also, Davis, P., Testimony Before the House Committee on Science and Technology on Ground Water Quality Research and Development, House Document No. 80, 1978.

Historically, a beneficial use was defined as an application of water which resulted in an economic gain to the appropriator, and which involved actual physical control over the water by diversion or retention. More recently, the doctrine has been extended in some states to recognize the importance of maintaining instream flows for the protection of fish and other instream values, wildlife, recreation, and the enhancement of water quality.

The process of appropriation can continue until all water in a stream is subject to rights of use through withdrawals from that stream. An appropriation right is based on the physical appropriation of water rather than on ownership of land abutting a stream; hence, the water may usually be put to use anywhere, by anyone.

Riparian Water Rights. Riparian water rights, characteristic of the eastern states, protect adjacent landowners from withdrawals or uses that unreasonably diminish surface water quantity and quality. Where diversions or uses have been unreasonable, either the parties have been enjoined, or adversely affected riparian owners have been compensated for interference with their rights. The concern of riparian law has been to protect private, rather than public rights in lakes and streams. Thus, under riparian law, each person whose land abuts a watercourse has two potentially contradictory rights. First, each riparian land owner has a right to natural flow--that is, the right to have the water flow to the property in its natural quantity and quality. Second, each riparian land owner on the watercourse has a co-equal right to make reasonable use of that water.

State Laws: Ground Water

Most ground water laws have been derived through case law in the courts. Many of these laws evolved before much was known about the hydrology of ground water movement. Legal concepts such as "absolute ownership" have been described by one observer as "little more than a formalized variant of the law of the jungle," whereby the landowner on a hydrologically superior position, or the landowner with the deepest well or biggest pump, will prevail over his neighbors.[2] Other rules, such as the "Eastern Correlative Rights" rule for percolating ground water and the comparable "reasonable use" rule for underground streams, emphasize the co-equality of every landowner and therefore, allow unlimited numbers of users access to the ground water supply. Such problems as ground water mining and land subsidence can result.

Federal Laws

Federal Reserved Water Rights. When the U.S. Government obtained the territories that are now the western states, it assumed sovereign domain over all the land, mineral resources, and water. The Federal reserved water doctrine provides that the United States implicitly reserves water sufficient for use on Federal lands.[3]

Indian Water Rights. Indian water rights orginate under Federal law, and thus exist independently of state laws. In most cases, these rights originated when an Indian reservation was created, and they pertain only to lands within a reservation. The legal principles governing Indian water rights and the reasons behind them were established by the U.S. Supreme Court in 1908 in the "Winters Doctrine."[4] In the doctrine, the U.S. Supreme Court held that there existed an implied reservation of rights to the use of waters that rise on, traverse, or border on Indian land, with a priority dating from the time of creation of the reservation. Since Indian water rights emanate from original Indian treaties with the United States, the treaties take precedence over state law under the supremacy clause of the U.S. Constitution. Thus, Indian water rights are not subject to control under state allocation systems. Indian water rights continue to be argued in U.S. courts--neither Indians nor non-Indians have a clear title.

Environmental Regulation of Water Resources

The environmental laws and regulations which affect water were identified and briefly described in Chapters 3 (Societal Trends), 6 (Water Pollutants), and 7 (Drinking Water). Prominent among these are the Clean Water Act (PL 95-217), the Resource Conservation and

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[2] Davis, P., Testimony Before the House Committee on Science and Technology on Ground Water Quality Research and Development, House Document No. 80, 1978.

[3] Hillhouse, R.A., "The Federal Reserved Water Doctrine--Application to the Problem of Water for Oil Shale Development," Land and Water Law Review, Vol. III, 1968.

[4] Winters v. United States, 207 U.S. 564, 1908.

Recovery Act (PL 94-580), and the Safe Drinking Water Act (PL 93-523). Under these and its other legislative mandates, EPA is charged with: (1) achieving and maintaining the physical, chemical, and biological integrity of ground and surface waters; (2) treating, containing, and controlling toxic and hazardous materials in solid waste; (3) protecting an adequate supply of high quality drinking water; and (4) developing integrated Federal, state, and local environmental management systems to minimize transfers of pollutants between media and identify optimal ultimate disposal strategies.[5]

8.2 U.S. WATER RESOURCE TRENDS

8.2.1 Introduction

The Water Resources Planning Act of 1965 directs the U.S. Water Resources Council to "maintain a continuing study of the nation's water and related land resources and to prepare periodic assessments to determine the adequacy of these resources to meet present and future water requirements."[6] In 1968, the Council reported its initial findings.[7] Since then, the Council has expanded its data bases and refined its methodologies in an effort to portray more accurately major U.S. water supply and use trends. The first product of this recent effort is the summary volume of the Second National Water Assessment, published by the Council in December 1978.[8]

The Second National Water Assessment reports data for 1975, 1985, and 2000. Data reported for 1975 are not actual data; they represent "assumed average conditions." For this reason, 1975 data appear in quotation marks throughout the rest of this chapter. It should also be noted that there are disagreements about some of the data and assumptions used and projections made in the Second National Water Assessment. As the Council states, the information should be viewed as "indicative." The report is used here because it represents the single best available summary of water resource management issues--issues which should be introduced in this Environmental Outlook report.

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[5] U.S. Environmental Protection Agency, Office of Planning and Management, EPA Agency Guidance for Fiscal Year 1980/81, Washington, D.C., April 1979, p. 16.

[6] Water Resources Planning Act of 1965 (PL 89-80).

[7] U.S. Water Resources Council, The Nation's Water Resources, Summary Report, U.S. Government Printing Office, Washington, D.C., 1968.

[8] U.S. Water Resources Council, The Nation's Water Resources: 1975-2000, Second National Water Assessment, Vol. I, Summary, Washington, D.C., U.S. Government Printing Office, December 1978.

8.2.2 Water Resource Regions

The Water Resources Council has divided the nation into 21 water resources regions for data collection and planning purposes (Figure 8-1). In addition, these major regions are further subdivided into 106 subregions. These regions are hydrologic areas consisting either of the drainage area of a major river or the combined drainage of several rivers.

8.2.3 The U.S. Water Budget

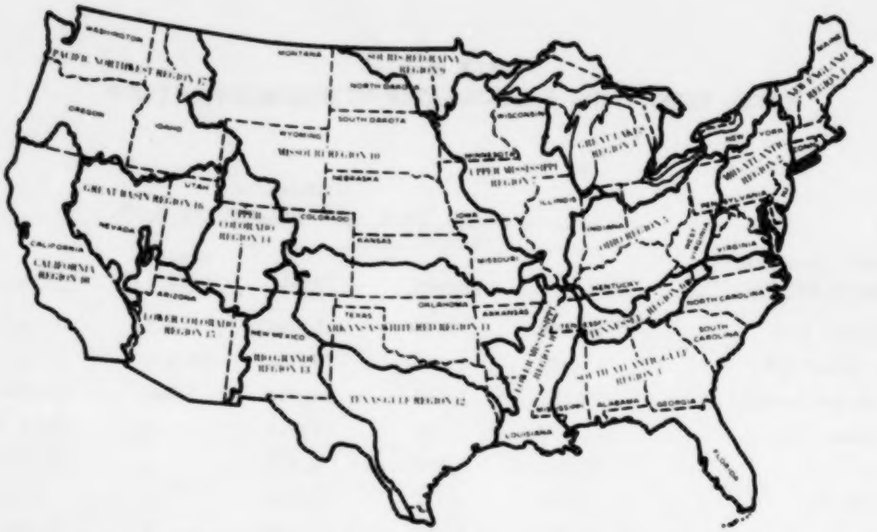
According to the Second National Water Assessment, on the average, about 4,200 billion gallons per day (bgd) is precipitated over the conterminous United States. Of this, about 2,750 bgd is evaporated or transpired. The remaining 1,450 bgd accumulates in ground or surface storage, flows to the oceans or across the nation's boundaries, evaporates from reservoirs, or is consumed. This figure constitutes the maximum amount of water available for use in the conterminous United States. However, with existing surface storage capacity and accounting for extremes in precipitation in 95 out of 100 years, 675 bgd is the amount of water available for use. The U.S. water budget is shown schematically in Figure 8-2.

8.2.4 Water Use

According to the Second National Water Assessment, total water withdrawals from surface and ground sources for use in the conterminous United States was about 393 bgd in "1975." These estimates, broken down by major water resources regions, are given in Table 8-1. As the table indicates, of this amount, 254 bgd were from fresh surface water sources, 81 bgd were from ground water sources, and 57 bgd were from saline sources.

Total freshwater withdrawals for all major offstream uses, including Alaska, Hawaii, and the Caribbean, were about 339 bgd in "1975." Based on assumptions about increased conservation and efficiency and improved technology, this total withdrawal is projected to decline by 9 percent in 2000, to 306 bgd. However, offstream water consumption (107 bgd in "1975") is projected to increase 27 percent by 2000, to 135 bgd. This factor is important since water consumed is not available for other downstream uses or as a source for recharging aquifers.

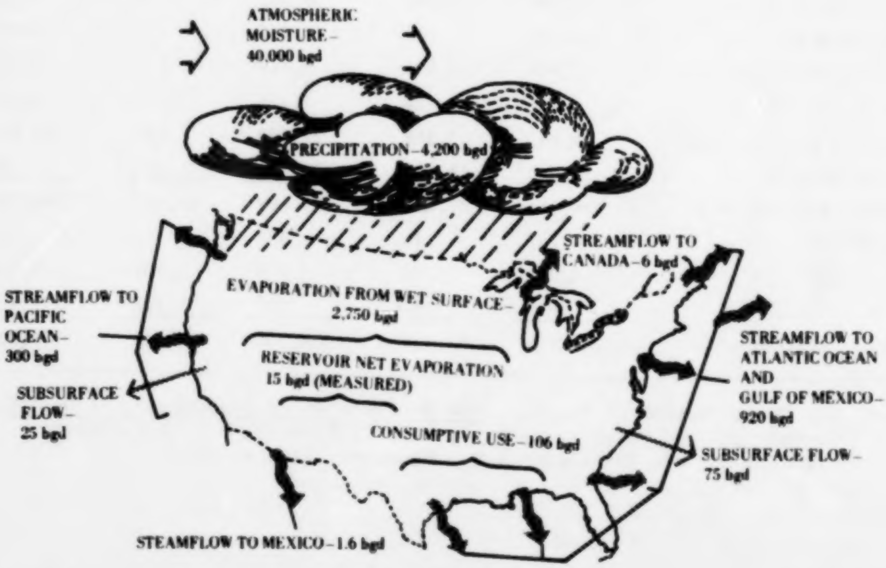
Comparative data on total freshwater withdrawals and consumption for "1975," 1985, and 2000 are presented in Table 8-2 for the major water resources regions.



WASHINGTON
PACIFIC NORTHWEST REGION 17
MONTANA
SOURIS-RED-RAINY REGION 9
NORTH DAKOTA
OREGON
IDAHO
SOUTH DAKOTA
WYOMING
MISSOURI REGION 10
NEBRASKA
GREAT BASIN REGION 16
UTAH
NEVADA
UPPER COLORADO REGION 14
COLORADO
KANSAS
CALIFORNIA
CALIFORNIA REGION 18
ARIZONA
LOWER COLORADO REGION 15
NEW MEXICO
RIO GRANDE REGION 13
TEXAS
ARKANSAS-WHITE-RED REGION 11
OKLAHOMA
TEXAS-GULF REGION 12
WISCONSIN
MINNESOTA
UPPER MISSISSIPPI REGION 7
IOWA
ILLINOIS
MISSOURI
ARKANSAS
GREAT LAKES REGION 4
INDIANA
OHIO REGION 5
WEST VIRGINIA
KENTUCKY
TENNESSEE
TENNESSEE REGION 6
LOWER MISSISSIPPI REGION 8
MISSISSIPPI
LOUISIANA
ALABAMA
GEORGIA
SOUTH ATLANTIC-GULF REGION 3
FLORIDA
SOUTH CAROLINA
NORTH CAROLINA
VIRGINIA
PENNSYLVANIA
NEW YORK
MID-ATLANTIC REGION 2
CONN.
MAINE
NEW ENGLAND REGION 1

Source: U.S. Water Resources Council, The Nation's Water Resources: 1975-2000, Second National Water Assessment, Vol. I, Summary, U.S. Government Printing Office, Washington D.C., December 1978. p. 5.

FIGURE 8-1
WATER RESOURCES REGIONS



ATMOSPHERIC MOISTURE–40,000 bgd
PRECIPITATION–4,200 bgd
STREAMFLOW TO CANADA–6 bgd
EVAPORATION FROM WET SURFACE–2,750 bgd
RESERVOIR NET EVAPORATION 15 bgd (MEASURED)
STREAMFLOW TO PACIFIC OCEAN–300 bgd
SUBSURFACE FLOW–25 bgd
STREAMFLOW TO ATLANTIC OCEAN AND GULF OF MEXICO–920 bgd
CONSUMPTIVE USE–106 bgd
SUBSURFACE FLOW–75 bgd
STEAMFLOW TO MEXICO–1.6 bgd

Source: U.S. Water Resources Council, The Nation's Water Resources: 1975-2000, Second National Water Assessment, Vol. I, Summary, U.S. Government Printing Office, Washington D.C., December 1978. pp. 30,31.

FIGURE 8-2
THE U.S. WATER BUDGET

TABLE 8-1
TOTAL FRESH- AND SALINE-WATER WITHDRAWALS, "1975"

Water Resources Region and No.	Withdrawls (in million gallons per day)				
	Freshwater				
	Surface	Ground	Total	Saline Water	Total
New England (1)	4,463	635	5,098	5,216	10,314
Mid-Atlantic (2)	15,639	2,661	18,300	19,625	37,925
South Atlantic-Gulf (3)	19,061	5,449	24,510	7,460	31,970
Great Lakes (4)	41,598	1,215	42,813	0	42,813
Ohio (5)	33,091	1,843	34,934	0	34,934
Tennessee (6)	7,141	271	7,412	0	7,412
Upper Mississippi (7)	10,035	2,366	12,401	0	12,401
Lower Mississippi (8)	9,729	4,838	14,567	1,253	15,820
Souris-Red-Rainy (9)	250	86	336	0	336
Missouri (10)	27,609	10,407	38,016	0	38,016
Arkansas-White-Red (11)	4,022	8,846	12,868	0	12,868
Texas-Gulf (12)	9,703	7,222	16,925	9,163	26,088
Rio Grande (13)	3,986	2,335	6,321	0	6,321
Upper Colorado (14)	6,743	126	6,869	0	6,869
Lower Colorado (15)	3,909	5,008	8,917	0	8,917
Great Basin (16)	6,567	1,424	7,991	0	7,991
Pacific Northwest (17)	30,147	7,348	37,495	131	37,626
California (18)	20,476	19,160	39,636	14,569	54,205
Total, Regions 1-18	254,169	81,240	335,409	57,417	392,826
Alaska (19)	261	44	305	57	362
Hawaii (20)	1,089	790	1,879	1,139	3,018
Caribbean (21)	653	254	907	1,124	2,031
Total, Regions 1-21	256,172	82,328	338,500	59,737	398,237

Source: U.S. Water Resources Council, The Nation's Water Resources: 1975-2000, Second National Water Assessment, Vol. I, Summary, U.S. Government Printing Office, Washington D.C., December 1978. p. 25.

TABLE 8-2
TOTAL FRESHWATER WITHDRAWALS AND CONSUMPTION - "1975," 1985, 2000
(IN MILLION GALLONS PER DAY)

Water Resources Region and Number	Withdrawals			Consumption		
	"1975"	1985	2000	"1975"	1985	2000
New England (1)	5,098	3,939	3,230	481	647	1,063
Mid-Atlantic (2)	18,300	15,857	13,873	1,843	2,472	3,548
South Atlantic-Gulf (3)	24,510	25,457	28,340	4,867	6,772	10,053
Great Lakes (4)	42,813	32,666	25,623	2,598	3,300	4,693
Ohio (5)	34,934	27,838	16,925	1,798	2,527	4,332
Tennessee (6)	7,412	7,131	6,013	313	647	1,105
Upper Mississippi (7)	12,401	10,386	7,910	1,145	1,604	2,688
Lower Mississippi (8)	14,567	17,453	24,841	4,027	4,554	5,511
Souris-Red-Rainy (9)	336	329	587	112	204	446
Missouri (10)	38,016	48,037	44,359	15,469	19,206	19,913
Arkansas-White-Red (11)	12,868	13,799	13,337	8,064	8,769	8,887
Texas-Gulf (12)	16,925	15,932	14,991	11,259	10,227	10,529
Rio Grande (13)	6,321	6,204	5,633	4,240	4,320	4,016
Upper Colorado (14)	6,869	7,841	7,519	2,440	3,018	3,232
Lower Colorado (15)	8,917	8,528	7,857	4,595	4,754	4,708
Great Basin (16)	7,991	7,316	7,258	3,779	3,765	4,036
Pacific Northwest (17)	37,495	38,098	33,852	11,913	14,610	15,196
California (18)	39,636	40,549	41,265	26,641	27,932	29,699
Total, Regions 1-18	335,409	327,360	303,413	105,584	119,328	133,655
Alaska (19)	305	433	745	58	207	459
Hawaii (20)	1,879	1,619	1,349	605	636	666
Caribbean (21)	907	963	890	343	374	300
Total, Regions 1-21	338,500	330,375	306,397	106,590	120,545	135,080

Source: U.S. Water Resources Council, The Nation's Water Resources: 1975-2000, Second National Water Assessment, Vol. I, Summary, U.S. Government Printing Office, Washington D.C., December 1978. p. 48.

In terms of freshwater use, agriculture and steam electricity generation account for most water withdrawals and consumption. The relative share of water withdrawals and consumption in these two sectors is not expected to change significantly between "1975" and 2000. This is shown in Table 8-3.

On the consumption side, agricultural uses dominate due to the high rate of evaporation related to irrigated agriculture. According to Second National Water Assessment projections, total consumption for agricultural water use will increase between "1975" and 2000, but the relative proportion used by agriculture will decrease because of anticipated increases in water consumption due to growth in steam electric generating and manufacturing activities. These changes are illustrated in Figure 8-3.

8.2.5 Functional Water Use Trends

The major offstream water uses are classified by function: domestic and commercial, manufacturing, agriculture, energy production, and minerals production. The following brief discussion of these uses is based on the Second National Water Assessment.

Domestic and Commercial

In "1975," about 83 percent of the urban population obtained water from central supply systems. This is projected to increase to 90 percent in 2000. There is little regional variation in water used for domestic and commercial purposes. In the conterminous United States, freshwater withdrawals for domestic and commercial uses were 28 million gallons per day (mgd) in "1975." This is projected to increase to 36 mgd in 2000. Consumption in this use category was 7 mgd in "1975," increasing to slightly more than 9 mgd in 2000. Most of the increases projected for this category of water use are related to assumptions about anticipated population increases rather than changes in patterns of use.

Manufacturing

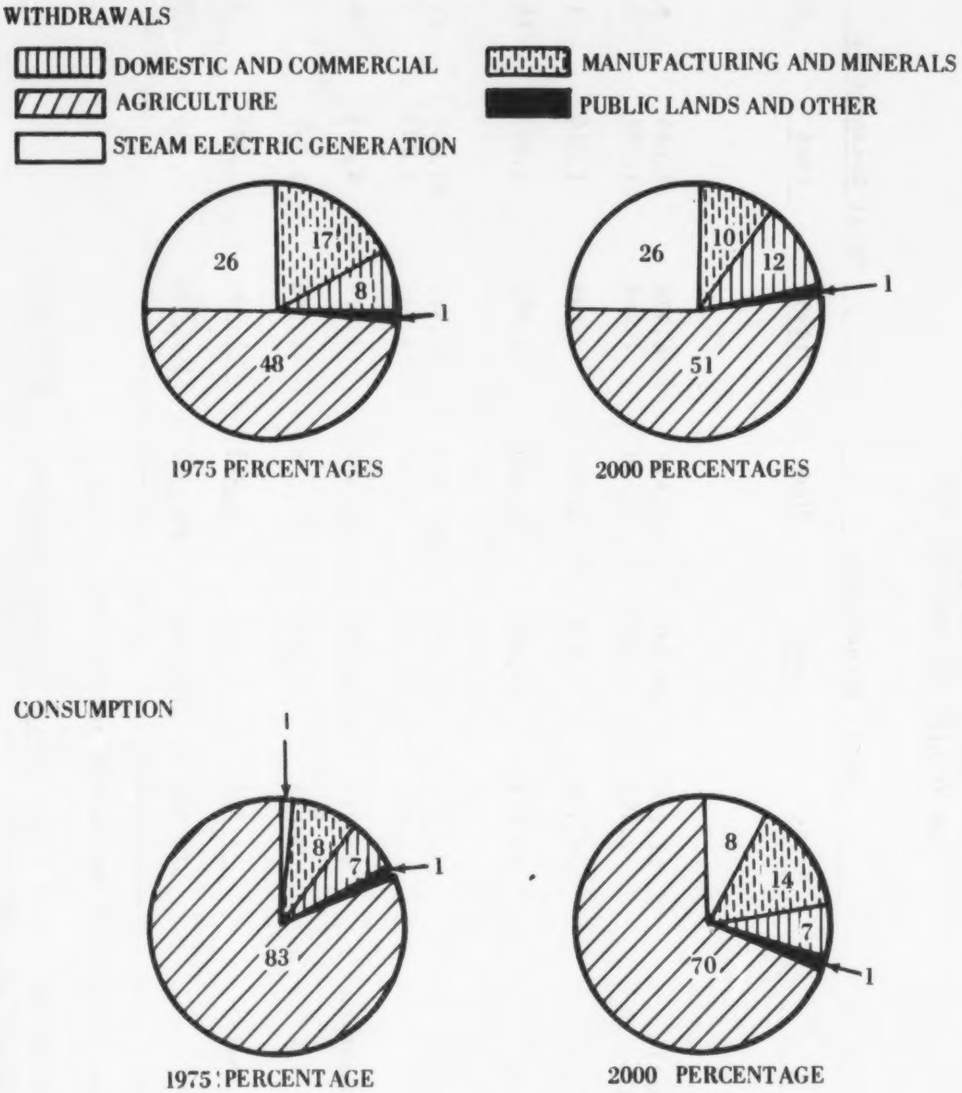
For the manufacturing sector, the Second National Water Assessment projects a sharp decline in water withdrawals, from about 51 mgd in "1975" to a little over 19 mgd in 2000. This is based on the assumption that pollution control regulations will result in water management changes that will significantly increase in-plant water recycling. However, total consumption is projected to increase from nearly 6 mgd in "1975" to about 15 mgd in 2000. This is largely related to evaporation losses associated with higher recycling temperatures.

TABLE 8-3
TOTAL WITHDRAWALS AND CONSUMPTION, BY FUNCTIONAL USE, FOR THE 21 WATER RESOURCE REGIONS "1975," 1985, 2000
(IN MILLION GALLONS PER DAY)

Functional Use	Total Withdrawals			Total Consumption		
	"1975"	1985	2000	"1975"	1985	2000
Freshwater:						
Domestic:						
Central (municipal)	21,164	23,983	27,918	4,976	5,665	6,638
Noncentral (rural)	2,092	2,320	2,400	1,292	1,408	1,436
Commercial	5,530	6,048	6,732	1,109	1,216	1,369
Manufacturing	51,222	23,687	19,669	6,059	8,903	14,699
Agriculture:						
Irrigation	158,743	166,252	153,846	86,391	92,820	92,506
Livestock	1,912	2,233	2,551	1,912	2,233	2,551
Steam electric generation	88,916	94,858	79,492	1,419	4,062	10,541
Minerals industry	7,055	8,832	11,328	2,196	2,777	3,609
Public lands and others[1]	1,866	2,162	2,461	1,236	1,461	1,731
Total freshwater	338,500	330,375	306,397	106,590	120,545	135,080

[1] Includes water for fish hatcheries and miscellaneous uses.

Source: U.S. Water Resources Council, The Nation's Water Resources: 1975-2000, Second National Water Assessment, Vol. I, Summary, U.S. Government Printing Office, Washington D.C., December 1978. p. 29.



WITHDRAWALS

1975 PERCENTAGES

2000 PERCENTAGES

CONSUMPTION

1975 PERCENTAGE

2000 PERCENTAGE

Source: U.S. Water Resources Council, The Nation's Water Resources: 1975-2000, Second National Water Assessment, Vol. I, Summary, U.S. Government Printing Office, Washington D.C., December 1978. p. 5.

FIGURE 8-3
DISTRIBUTION OF TOTAL FRESHWATER WITHDRAWALS AND CONSUMPTION BY FUNCTIONAL USE
1975 AND 2000

Agriculture

Water for irrigated agriculture represents the largest water use both for withdrawals and consumption. The Second National Water Assessment projects a slight decline in withdrawals between "1975" and 2000, from 157 mgd in "1975" to 153 mgd in 2000, due primarily to use limitations as a result of ground water overdrafts in the Southwest and increased irrigation efficiency. Agricultural water consumption is projected to increase from about 86 mgd in "1975" to nearly 97 mgd in 2000 due to increases in irrigated acreage.

Energy Production

According to the Second National Water Assessment, steam-powered electricity generation accounted for 95 percent of all energy-related, freshwater withdrawals in "1975." Water withdrawals are projected to increase between "1975" and 1985, from about 89 mgd to 94 mgd, but to decrease significantly by 2000, to 79 mgd, due to expected advances in cooling technology. However, water consumption is projected to increase sharply, from about 1.4 mgd in "1975" to nearly 11 mgd in 2000, largely as a result of greater evaporation losses during recycling processes.

Minerals Industry

Both water withdrawals and consumption are projected to increase in this economic sector. The Second National Water Assessment projects that withdrawals will grow from about 7 mgd in "1975" to nearly 11 mgd in 2000. Water consumption for the minerals industry is expected to increase from slightly more than 2 mgd in "1975" to more than 3 mgd in 2000. These increases are based on projected growth in the minerals industry and do not assume much improvement in either water use efficiency or recycling/reuse. While the percentage growth rate of water withdrawals and consumption is projected to be high, the mineral industry's share of national water consumption will remain at about 2 to 3 percent.

8.2.6 Instream Water Use

Instream-flow use refers to the "amount of water flowing through a natural stream channel needed to sustain the instream values at an acceptable level."[9] These values include maintenance of fish and wildlife populations, outdoor recreation, navigation, hydroelectric generation, waste assimilation, conveyance to downstream points of diversion, and ecosystem maintenance (estuaries, riparian vegetation, flood-plain wetlands). According to the Second National Water Assessment, fish and wildlife use is the dominant instream-flow use in all regions. In terms of outdoor recreation, about 20.3 million acres of surface water are currently accessible. The Second National Water Assessment projects a cumulative demand for 10 million additional acres in 1985, and another 13 million in 2000. Currently, hydroelectric generation supplies about 15 percent of the national supply of electricity. The Second National Water Assessment projects an increase of about 6 percent by 2000. While it is doubtful that major hydroelectric facilities will be constructed during this period, recent developments in low-head flow generation and the rising costs of other energy sources may renew interest in hydroelectric generation.

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[9] U.S. Water Resources Council, The Nation's Water Resources: 1975-2000, Second National Water Assessment, Vol. I, Summary, Washington, D.C., U.S. Government Printing Office, December 1978, p. 42.

The Second National Water Assessment anticipates no major change between "1975" and 2000 in the instream-flow used for navigation. The nation's inland and intracoastal waterway network now consists of more than 25,000 miles of navigable channels and canals.

Issues surrounding identifying, quantifying, and managing the conflicts between the various and sometimes competing instream-flow use values will continue to intensify. Not all instream uses can be maximized simultaneously. Increased recognition of the importance of instream flow for water quality, definitions of "beneficial" use to include water required for fish and wildlife, and growing demands to preserve free flowing streams are certain to result in conflicts.

8.3 IMPLICATIONS

8.3.1 Overview

The Second National Water Assessment concludes that "overall, the nation's water supplies generally are sufficient to meet water needs for all beneficial purposes."[10] However, major water problems exist in nearly all portions of the country. The Second National Water Assessment identifies 10 serious water resource-related problems: inadequate surface water supply; overdraft of ground water; pollution of surface water; pollution of ground water; drinking water quality; flooding, erosion, and sedimentation; dredge and fill; wet-soils drainage and wetlands; and degradation of bay, estuary, and coastal waters. Environmental problems associated with the pollution of surface water and ground water supplies are discussed at length in Chapter 6 of this report. Drinking water problems are analyzed in Chapter 7. The remainder of this section will discuss briefly those water problems identified in the Second National Water Assessment not discussed elsewhere in Environmental Outlook 1980. In addition, this section includes an analysis of the water demands of increased energy production based on SEAS-derived growth projections.

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[10] U.S. Water Resources Council, The Nation's Water Resources: 1975-2000, Second National Water Assessment, Vol. I, Summary, Washington, D.C., U.S. Government Printing Office, December 1978, p. 53.

8.3.2 Select Water Resource Issues

Inadequate Surface Water Supply

Most water resources regions now have, or are projected by the Second National Water Assessment to face, problems supplying surface water for all desired uses. In general, instream flows are considered inadequate in the southwest, the lower Colorado, and much of the High Plains Region extending from Texas to Nebraska. Competing offstream uses and increased recognition of the importance of instream values will result in water shortages in many portions of the nation. Decisions on what uses water will serve are among the most important we face.

Overdraft of Ground Water

Ground water overdraft is a severe problem in central California, south central Arizona, the Texas Gulf Coast, the lower Mississippi, the eastern portions of Wisconsin and Illinois, the east coast of North Carolina, and the High Plains Region. Among the problems associated with ground water overdraft is that continuation of current trends will result in a sharp decline in irrigated agriculture as the energy costs of pumping increase.

Flooding

Flooding continues to be a serious problem. According to the Second National Water Assessment, in 1975, 107 people died in floods and the estimated potential flood-related property damages was $3.4 billion. Second National Water Assessment projections for 2000 put this figure at $4.3 billion.

Erosion and Sedimentation

Erosion is a natural process that can be greatly accelerated by human activities. The average for soil loss from agricultural erosion in "1975" was estimated by the Second National Water Assessment at 9 tons per acre, with losses of over 25 tons per acre in some areas. The Second National Water Assessment considers erosion and sedimentation to be the most pervasive water-related problem in the United States.

Dredge and Fill

The deposition of sediment in harbors, navigable channels, and reservoirs requires removal and disposal. Perhaps the most significant impact connected with dredging and disposal is its effect on wetland ecosystems.

Wet-Soils Drainage and Wetlands

According to estimates used in the Second National Water Assessment, there are approximately 74 million acres of wetlands in the United States. It has been estimated that, between 1955 and 1975, about 6 million acres of wetlands were destroyed. Given the roles wetlands play and the desire to drain wetlands for other uses, careful attention to assessing impacts will be required.

Water for Energy

Water is always needed for energy development--e.g., coal mining, land reclamation, coal liquefaction and gasification, coal slurry pipelines, oil shale conversion, fuel refining, and thermal electric power generation. In energy development planning, water availability, especially near coal and oil shale deposits, must always be considered. In addition, the priorities and trade-offs associated with water and energy and preferences in standard of living and quality of life must also be considered.

The major impacts of accelerated development of oil shale and coal will be increasing demands on scarce western water resources and increased hazards of environmental damage to water resources and aquatic life. Problems will likely arise from mining, thermal discharges, discharge of trace elements of toxic materials, and reduced flows associated with greater consumptive use. Moreover, oil, gas, and ground water pumpage in coastal areas will increase problems of saltwater intrusion and land subsidence.[11]

Although steam electric generation and manufacturing water consumption estimated for 1975 accounts for only a small fraction of the national water consumption--just over 1 percent and almost 8 percent, respectively--projected increases approaching 8 percent and 14 percent, respectively (see Figure 8-3), for the year 2000, may have significant implications at local and regional levels.

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[11] Haimes, Y.Y., Water for Energy Development: 1975-2000, Internal Report Prepared for the Office of Technology Assessment, U.S. Congress, September 1977.

Water consumed by producing synthetic fuels from coal, particularly synthetic gas, is projected to increase from zero in 1975 to about 0.5 bgd in the Low Growth Scenario, and to about 0.8 bgd in the High Growth Scenario.[12] Although this industry represents only about 7 percent of the total industrial water consumption projected in 2000 under High Growth assumptions and about 4 percent in the Low Growth Scenario, it is anticipated that this industry will situate primarily in the water-short regions west of the Mississippi and parts of the South Central, Central, and Mountain Regions (Federal Regions VI, VII, VIII), where the impacts of this consumption may be significant. On the other hand, fewer impacts from energy and manufacturing industries are expected in the Middle Atlantic, Southeast, Great Lakes, and some parts of the South Central Regions (Federal Regions III, IV, V, and portions of VI), because no increase in water consumption is projected beyond the current 3.3 bgd level. The highest impact is expected in the Mountain Region (Federal Region VIII), where the estimated 1975 water consumption level of 56 mgd is expected to increase to 446 mgd in the Low Growth Scenario and to 732 mgd in the High Growth Scenario.

The projected development of coal and oil shale is expected to have significant regional and local impacts on the agricultural sector. Specifically, farm and ranch lands and their associated water rights are being sold to energy companies. Because of the very large price differential between water for irrigation and water for energy, this pattern is expected to accelerate. The corresponding economic and social impacts and implications are likely to be of significant local and regional importance.

8.4 SUMMARY: WATER CONSERVATION AND REUSE

8.4.1 Overview

Overall, the nation does not face a water crisis. But, as described in Section 8.3, nearly every region faces some type of water problem; some of these problems exist now, and future ones are expected to be quite severe. The Second National Water Assessment concludes that, to avert a crisis, more attention will have to be paid to improving the efficiency of current water uses and establishing more equitable procedures for allocating water in areas where supplies for all desired uses are unavailable.

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[12] SEAS assumptions used to project the various energy uses in the High Growth and Low Growth Scenarios are discussed in Appendixes A and B of this report.

The Second National Water Assessment reviews a number of conservation and augmentation strategies--improved irrigation, weather modification, desalination, improved surface water management, and water reuse. Agricultural irrigation and water reuse are discussed here because improved irrigation practices could contribute substantially to water conservation and because water reuse technology is being tested by the Environmental Protection Agency.

8.4.2 Agricultural Irrigation

Agricultural irrigation is the major freshwater user in the United States, having accounted for an estimated 81 percent of total U.S. water consumption in 1975.

Of the water stored or diverted for irrigation, less than half reaches the intended crops. The U.S. Department of Agriculture estimates that average off-farm loss is about 22 percent, and on-farm loss (which includes some ditch losses) is about 37 percent, for a total of 59 percent lost. Some of the losses are ascribed to evaporation and weeds, but in large measure, they result from unlined conveyance channels. Of the 14,323 miles of canals operated by the Bureau of Reclamation, 85 percent are unlined. Of the 34,294 miles of laterals, 68 percent are unlined.[13]

Although in some cases a large fraction of the lost irrigation water may be recovered in return flows or percolation to useful aquifers, in many others, it is permanently lost. The Soil Conservation Service estimates that a high-efficiency irrigation program can reduce present gross irrigation withdrawals of 174 bgd by 43 bgd, and still provide for a 10 percent projected increase in the irrigated land area.

8.4.3 Water Reuse

In view of increasing water consumption, the number of reuse applications of water resources has been increasing continuously over the last decade. Stormwater can be routed to recharge basins to augment aquifer recharge. Some ways of reusing treated wastewater are for manufacturing, steam-powered electric generation, and irrigation; for augmenting water supply, either by aquifer recharge or blending in surface water reservoirs; and for creating a pressure barrier to protect freshwater aquifers from saltwater intrusion.

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[13] Executive Office of the President, Office of Science and Technology Policy, Scientific and Technological Aspects of Water Resource Policy, Washington, D.C., January 19, 1978.

Constraints on reusing wastewater are related to the intended use and the costs associated with improving its quality. Public health and safety are also critical concerns in water reuse. As new reuse applications are developed, the impact on wastewater treatment and sludge disposal will become significant.[14] Improved, higher level treatment methods will be needed, not only for routine wastewater constituents, but also for the removal of specific compounds.

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[14] Metcalf and Eddy, Inc., Wastewater Engineering Treatment, Disposal, Reuse, Second Edition, McGraw-Hill Book Company, New York, 1979, p. 8.

CHAPTER 9
MARINE POLLUTION

HIGHLIGHTS OF CHAPTER 9

- o The number of tanker-related oil spill incidents in U.S. coastal waters can be expected to decline between 1980 and 2000. However, because tanker sizes are increasing, individual spills may get larger, and the trend in total oil spill volume is unclear.
- o Offshore oil drilling is expected to increase. Although there has been no clear trend in associated spill volume in the last 8 years, the increased activity alone may bring an increase in the annual volume of oil spilled.
- o Dumping sewage sludge in the ocean is expected to diminish rapidly after 1980 because of a ban mandated by the Marine Protection, Research and Sanctuaries Act, but dumping of dredged material is expected to increase slightly.
- o Several other concerns are: municipal ocean outfalls from sewage treatment plants, industrial outfalls, entrance of toxic chemicals into the marine ecosystem, and the effects of deep sea mining of minerals.

9.1 INTRODUCTION

9.1.1 Problem Identification

This chapter provides information on trends and potential future environmental problems related to marine pollution to those engaged in planning EPA's environmental research program and other interested individuals, as discussed in the Introduction and Chapter One.

Global oceanic effects are important, and effects nearer shore are probably even more important. Pollutants produced by human activity tend to have large impacts on coastal and estuarine environments that are rich sources of marine productivity, and provide critical aesthetic, commercial, and recreational resources. They are heavily impacted because of their proximity to human populations; more than 100 million Americans now live within 50 miles of the coast.

In 1960 Rachel Carson gave the world a rather ominous warning about the consequences of dumping radioactive wastes in the ocean. She said "It is a curious situation that the sea, from which life first arose, should now be threatened by the activities of one form

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of that life. But the sea, though changed in a sinister way, will continue to exist; the threat is rather to life itself."[1] Scientific data being developed then indicated that the effects of increased levels of radiation in the ocean environment could be severe. With this data in mind, the Atomic Energy Commission placed a moratorium on issuing new licenses for the disposal of radioactive wastes in the marine environment in late 1960. By 1963, dumping radioactive materials off U.S. coastal waters had been drastically curtailed; dumping ceased in 1970.

However, as dumping radioactive materials was phased out, dumping non-radioactive wastes in the ocean became increasingly common. Municipalities, faced with the need to dispose of large quantities of sewage sludge and other waste materials, turned to ocean dumping for a solution to their problem. Industries confronted with increasing volumes of chemical waste and the high cost of waste disposal, regarded ocean dumping as an inexpensive alternative to costly land disposal methods.

At the same time, the increased reliance of the U.S. on foreign oil was bringing millions of gallons of petroleum into our ports. Increasing oil tanker traffic resulted in increased oil pollution from accidents and standard shipping practices, such as tank cleaning and deballasting.

Until recently, many individuals incorrectly assumed that small amounts of pollution in such a vast body of water as the ocean would be relatively harmless. The "drop in the bucket" concept dominated U.S. public thinking until the late 1960s and early 1970s when communities began finding waste materials washing up on shorelines, harmful bacteria in waters off recreational beaches, and tainted seafood in fishing areas. Scientific data documenting the adverse effects of wastes resulting from human activities on the marine environment and the potential effects on humans, exposed the myth that the ocean could absorb large quantities of pollutants with minimal or no ecological effects. One consequence of this discovery was that provisions in various Federal legislative mandates began to address more seriously the issue of marine pollution.

9.1.2 Regulatory Background

The Marine Protection, Research and Sanctuaries Act (PL 92-532), the Federal Water Pollution Control Act Amendments (PL 92-500), the Ports and Waterways Safety Act, and the Coastal Zone Management Act

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[1] Carson, Rachel, The Sea Around Us, New York, Oxford University Press, rev. ed. 1961.

(PL 95-583), all of 1972, deal either exclusively or in part with the marine protection issue. More recently, the Clean Water Act of 1977 (PL 95-217), and the Ocean Pollution Research and Development and Monitoring Planning Act and the Port and Tanker Safety Act (PL 95-474), both of 1978, expanded the Federal government's role in this area. Regulatory information is discussed further in each of the following sections.

9.1.3 Data Sources and Quality

Historical data are available for the last decade or so from several annual reports[2] from the U.S. Coast Guard, the Council on Environmental Quality, and the Environmental Protection Agency. These reports are useful for analyzing U.S. trends. Future projections are generally not available, so most discussion of future trends is qualitative. Although marine pollution has global dimensions when the deep ocean is considered, the trends discussed here deal with coastal waters, and, like most of this report, are restricted almost entirely to the United States.

9.1.4 Organization of Chapter

Historical trends in quantities of pollutants entering the ocean show the positive effects of the various legislative efforts. In projecting future trends in marine pollution, the potential impacts of the more recent legislative initiatives are taken into account. The discussion focuses on the short- and long-term trends of major sources of pollution in the marine environment: accidental oil spills and intentional dumping or discharges of waste materials. Other important topics, such as impacts associated with power plants, marine mineral resource extraction, and toxic chemical pollution, will also be briefly discussed.

The inadequate historical data base, as well as the probable impact of increasing legislative interest in the oceans, render any attempt to project the future a very risky activity. The emphasis, therefore, has been to identify the sources and general magnitude of trends, rather than attempt precise numerical estimates.

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[2] These include: U.S. Coast Guard, Polluting Incidents In and Around U.S. Waters (annually since 1973); Council on Environmental Quality, Environmental Quality (annually since 1970); and U.S. Environmental Protection Agency, Annual Report by the U.S. Environmental Protection Agency on Administration of the Ocean Dumping Permit Program (annually since 1973).

9.2 OIL SPILLS

9.2.1 Environmental Effects

The recent massive oil spill from the Ixtoc I off-shore well blow-out in Campeche Bay, off the Mexican coast, and the Amoco Cadiz supertanker spill off the northern coast of France, provided the world with dramatic examples of some of the immediate environmental effects of large-volume oil spills: oily beaches, devastated fisheries, and black waves laden with petroleum. Due to the ocean's natural cleansing process, these more visible damages frequently are temporary, although they sometimes involve tremendous economic hardship and aesthetic displeasure. Scientists believe that the more subtle, long-term effects of an oil spill may be far more ecologically harmful.

Much of the present research on oil spills concentrates on the longer-term sublethal effects. Low levels of petroleum and petroleum products (at the parts per billion level) have been shown to affect plant and animal growth patterns, decrease rates of photosynthesis, disrupt feeding and reproductive behavior, and seriously impair other vital biological processes. Investigations into the transport and fate of petroleum hydrocarbons and the means by which fish and other organisms metabolize low levels of these pollutants are continuing.

For the past several years, researchers at the Woods Hole Oceanographic Institution have studied a relatively small (175,000 gallon) oil spill near West Falmouth, Massachusetts. This study, considered to be the most rigorous and comprehensive investigation ever made into a single spill event, showed that: 1) there was severe local mortality of the plants and animals of the intertidal marsh and subtidal soft-bottom communities; 2) impacted communities required years for recovery; and 3) the oil was persistent, especially in the marsh areas which served as a source of recontamination by continuously oozing oil. Years after the spill, traces of oil were found in plants and animals within the spill area. The communities were compromised by the persistent and shifting oil; sublethal effects of chronic oil pollution were apparent for at least 7 years after the spill. There also was a loss of marsh grass; this reduces the effectiveness of the marsh as a nursery area for marine organisms, a runoff water purification system, and a land stabilization mechanism.[3]

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[3] U.S. Environmental Protection Agency, Office of Research and Development, Decision Series: A Small Oil Spill at West Falmouth, EPA-600/9-79-007, 1979, p. 25.

9.2.2 Regulatory Mandates

Following the 1969 Santa Barbara offshore well blow-out, Congress enacted the Water Quality Improvement Act of 1970 (PL 91-224). This Act included a section regulating the discharge of oil into traditional navigable waters within three miles of the U.S. coastline.

Section 311 of the Federal Water Pollution Control Act, as amended in 1972 (PL 92-500), specifies a three-part approach to the control of oil spills: response, prevention, and enforcement. Regulations promulgated under the authority of this Act require the preparation of a Spill Prevention, Control, and Countermeasure (SPCC) plan by the owner or operator of any facility that might spill oil into U.S. waters.[4] The Port and Tanker Safety Act of 1978 gives the Secretary of Transportation authority to regulate all stages of transporting oil by tanker. The Coast Guard is adopting new international tanker safety standards agreed upon by the Intergovernmental Maritime Consultative Organization (IMCO) which became effective in 1979 for new ships, and will go into effect in 1981 through 1985 for existing ships.[5]

The Deepwater Port Act of 1974 (PL 93-627) contains provisions to protect the environment from tanker and pipeline spills associated with deep water ports off the U.S. coast. Finally, the Outer Continental Shelf Lands Act (PL 93-627) gives the Secretary of Interior authority to control the leasing of offshore oil and gas drilling sites, and contains provisions for environmental protection.

Another indication of Federal commitment in controlling marine pollution is the draft legislation proposed by the Administration to provide a system for responding to, assigning liability for, and ensuring compensation for the release of oil and hazardous wastes into the marine environment. The proposed Oil, Hazardous Substances and Hazardous Waste Response, Liability, and Compensation Act of 1979, more commonly known as the "Superfund" bill,[6] is presently being considered by several Congressional committees. If enacted as presently written, the law will establish a $1.6 billion fund to pay for cleaning up both terrestrial and aquatic oil and hazardous chemical spills. It is expected that "Superfund" will encourage more careful handling of oil and hazardous materials through provisions allowing for the recovery of cleanup costs from those responsible for a spill or dumping incident.

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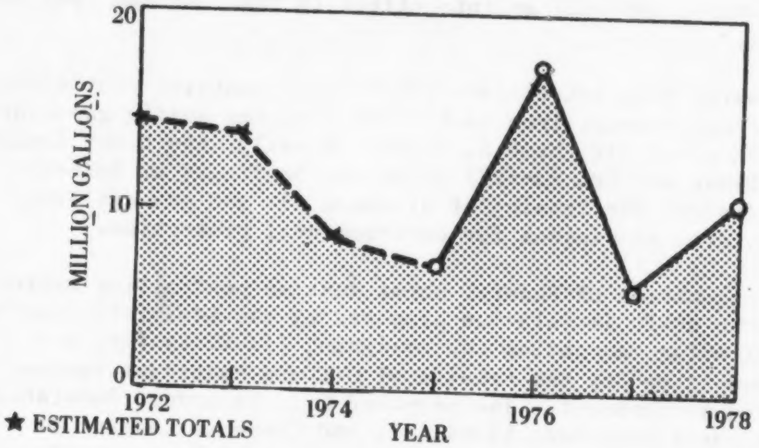
[4] U.S. Environmental Protection Agency, Oil and Special Materials Division, Oil Spills and Spills of Hazardous Substances, Washington, D.C.: Government Printing Office, March 1977, pp. 3-5.

[5] Council on Environmental Quality, Environmental Quality-1978, U.S. Government Printing Office, Washington, D.C., 1979, pp. 366-367.

[6] Communication from the President of the United States to the 96th Congress, House Document No. 96-149, June 13, 1978.

9.2.3 Trends in Oil Spills

For the past six years, spills of petroleum off U.S. coastal waters have averaged approximately 11 million gallons annually (see Figure 9-1).[7] Major vessel spills can easily boost annual totals. The 1976 Argo Merchant spill of 7.5 million gallons off of Nantucket, Massachusetts, resulted in a yearly total of approximately 18 million gallons. The Mexican off-shore well blow-out will have a dramatic effect on the 1979 totals (to be released by the U.S. Coast Guard in late 1980).



Source: U.S. Coast Guard, Polluting Incidents In and Around U.S. Waters (published annually since 1973).

FIGURE 9-1
VOLUME OF OIL SPILLED IN U.S. COASTAL WATERS
1972-1978

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[7] U.S. Coast Guard, Polluting Incidents In and Around U.S. Waters, (annually, since 1973).

Trends in Oil Spills from Tanker Ships

U.S. Coast Guard figures on the annual tanker ship oil spill incidents and volumes for the years 1975 to 1978 are shown in Table 9-1 below.

TABLE 9-1
TANKER SHIP OIL SPILLS, 1975-1978

	1975	1976	1977	1978
Incidents	643	577	590	726
Volume (million gallons)	1.8	8.9	0.2	0.3

Source: U.S. Coast Guard, Polluting Incidents In and Around U.S. Waters (published annually since 1975).

If the volume of imported oil stays relatively constant or decreases slightly over the next 20 years, as the Department of Energy is predicting,[8] and if oil spill prevention regulations are expanded and existing laws improved, a gradually decreasing trend in the number of tanker ship oil spills would be anticipated. It cannot be assumed, however, that because oil spill incidents may decrease, the total annual volume of those spills will decrease. For example, as the number of supertankers increases, the number of large-volume tanker ship spills could be expected to increase, keeping total spill volume figures high. Thus, the complexity of the various factors involved and the lack of consistent trends in historical data, make the prediction of future spill volumes exceedingly difficult.

Trends in Oil Spills Related to Offshore Production

The Department of Interior's U.S. Geological Survey (USGS) is responsible for the day-to-day inspection and monitoring of Outer Continental Shelf (OCS) oil and gas operations. The USGS has kept records on spills associated with federally supervised drilling and production activities since 1971. Records of spills in the Gulf of

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[8] U.S. Department of Energy, Energy in Focus: Basic Data, DOE/OPA-0020, Washington, D.C., Government Printing Office, Jan. 1978, p. 6.

Mexico are especially comprehensive and are therefore most appropriate for trend analysis. In addition, the Gulf of Mexico has been the most active offshore oil and gas production area in the world for the past 30 years. Since 1947, approximately 13,000 wells have been drilled in federal waters, and almost 8,000 wells on 2,200 offshore platforms were operating by the end of 1977.

In its discussion of the difficulty in assessing offshore production oil spills trends, the USGS states that: "Oil spillage... can readily be misunderstood or distorted."[9] Some of the problems cited are interchanging statistical information from many different sources; combining high and low estimates for spills of different categories, such as drilling, production, and transportation, in a statistically invalid way (the correct overall high estimate is not as large as the sum of the individual high estimates); use of peak annual production for a given oil field, rather than average production over the life of the well; and inadequate consideration of future technical innovation. Finally, they point out that,

> The absence of universally recognized definitions for such terms as "major spill," "minor spill," and "blowout," allows considerable latitude in categorizing incidents. One observer could justifiably say that there has only been 1 major pollution incident in the history of OCS operations, whereas another might, with equal validity, cite 30 incidents.[10]

Table 9-2 contains historical information on the number of incidents and volume of offshore production-related oil spills on federally leased land in the Gulf of Mexico.

TABLE 9-2
OFFSHORE PRODUCTION-RELATED OIL SPILLS, GULF OF MEXICO OUTER CONTINENTAL SHELF, 1971-1978

	1971	1972	1973	1974	1975	1976	1977	1978
Incidents	1,256	1,161	1,175	1,137	1,128	951	868	876
Total Volume (thousand gallons)	116.7	49.6	970.0	982.3	41.0	219.9	53.8	72.2

Source: U.S. Geological Survey, Oil Spills, 1971-1975, Gulf of Mexico Outer Continental Shelf, USGS Circular 741. Data for 1976-1978 obtained from Elmer P. Danenberger, USGS, Reston, Virginia.

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[9] U.S. Geological Survey, Oil Spills, 1971-1975, Gulf of Mexico Outer Continental Shelf, USGS Circular 741, Washington, D.C., Government Printing Office, 1976.

[10] Ibid.

A gradually decreasing trend in incidents occurred between 1971 and 1978. The trend in total volume is mixed; incidents and volumes of spills do not generally correlate. During 1972 and 1973, for example, roughly the same number of spills occurred. However, the volume of oil spilled in 1973 was nearly 20 times the volume spilled in 1972.

The January 1969 oil production platform blow-out off Santa Barbara, California, resulted in a 700,000 gallon spill. Ten years later, the disastrous Mexican offshore blow-out released in excess of 100 million gallons in the worst oil spill in history.

What these occurrences and the Gulf of Mexico data indicate is that offshore drilling is a very hazardous undertaking. Despite extensive safety precautions, major spills have and will continue to occur. Since less than 5 percent of the potentially productive area of the continental shelf has been leased to date,[11] it is likely that drilling activities will increase. Fortunately, major disasters related to offshore drilling are rare, but the expansion in drilling activities will undoubtedly bring with it increased marine environmental degradation due to oil spills, drilling muds, and other pollutants related to resource extraction.

The quantity of drilling mud discharges will increase dramatically as outer continental shelf development increases. These muds contain numerous chemicals which may be environmentally unacceptable: from bactericides, calcium removers, and pH control products; to emulsifiers, lubricants, thinners, and foaming agents. This is a matter of concern since drilling muds often contain substances known to have carcinogenic effects. Some chemicals found in drilling muds are capable of accumulating in marine organisms, and others persist for years in bottom sediments.

9.3 OCEAN DUMPING

9.3.1 Environmental Effects

Three major categories of waste materials are presently being dumped into U.S. coastal waters: sewage sludge, industrial waste, and dredge spoils. The environmental effects associated with dumped wastes are dependent upon the quantity and types of pollutants contained in the dumped or discharged material. Dumping sewage sludge presents numerous problems including the washing ashore of garbage and grease, and the introduction of human pathogens, toxic organic chemicals, and heavy metals into the marine environment. Major concerns associated with dumping industrial waste are related to the persistence and bioaccumulation of toxic organic chemicals, metals, and other inorganic substances into the ocean. Dredged materials may disrupt marine communities affected by siltation, and may contain toxic or hazardous organic chemicals or trace metals.

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[11] U.S. Environmental Protection Agency, Workshop on National Needs and Priorities for Ocean Pollution Research and Development and Monitoring, EPA-600/8-79-012, Tysons Corner, Virginia, November 14-16, 1978, p. 38.

9.3.2 Regulatory Mandates

The dumping of sludge, industrial waste, and dredged materials is regulated by the Marine Protection, Research, and Sanctuaries Act of 1972 (PL 92-532). The 1977 Amendments to the Act require that no permits be issued for the dumping of sewage sludge after December 31, 1980.

It now appears, however, that because of the lack of economically viable alternative sewage sludge disposal options, there may be some dumping beyond the 1980 deadline. It is expected that this dumping will occur only after all possible alternatives to ocean dumping have been thoroughly examined, and only if the sludge is considered to be environmentally acceptable.

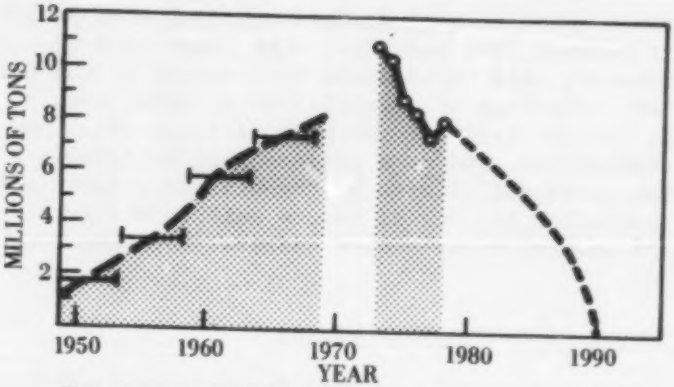
No specific date for terminating industrial waste dumping has been set. However, EPA is required to "prevent or strictly limit the dumping into ocean waters of any material which would adversely affect human health, welfare or amenities, or marine environment, ecological systems, or economic potentialities."

The regulation of dredge spoils dumping is mandated by Section 404 of the Clean Water Act, as amended in 1977. The Army Corps of Engineers is required to administer a permit system to control dumping, while the EPA is authorized to restrict dumping in areas which may be adversely affected ecologically.

9.3.3 Trends in Ocean Dumping Excluding Dredged Material

From 1949 to 1953, an average of 1.7 million tons per year of sewage sludge, industrial waste, construction and demolition debris, solid waste, explosives, chemical munitions, and radioactive wastes were dumped into the ocean. This quantity increased steadily, and between 1964 and 1968 averaged 7.4 million tons annually. After 1970 the dumping of radioactive wastes, explosives, and chemical munitions was halted. The total quantity of dumped materials, including sewage sludge, industrial waste, construction and demolition debris, solid waste, incinerated wood, and incinerated chemicals rose to 10.9 million tons in 1973. With the implementation of the Marine

Protection Research and Santuaries Act, total annual dumping dropped to 7 or 8 million tons in 1977-1978 (see Figure 9-2).[12] It is expected that this downward trend will continue because of the congressionally mandated halt of sewage sludge dumping on or before December 31, 1981. Dumping of relatively benign industrial waste in the Atlantic Ocean will probably keep the total annual figures above 5 million tons until at least 1985. Industrial waste dumping in the Gulf of Mexico ceased in 1978 and has not occurred in the Pacific for several years. By 1990 all dumping of sewage sludge and industrial waste is expected to cease.



Note: Quantities from 1949 to 1968 are five year averages. Projections are based on regulatory schedules, see text.

Source: Council on Environmental Quality, Ocean Dumping: A National Policy, October 1970.
U.S. Environmental Protection Agency, Annual Report on Administration of the Ocean Dumping Permit Program, first through sixth editions.

FIGURE 9-2
TRENDS IN OCEAN DUMPING, EXCLUDING DREDGED MATERIAL
1949-2000

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[12] Council on Environmental Quality, Ocean Dumping: A National Policy, October 1970, p. 8. Also, U.S. Environmental Protection Agency, Annual Report on Administration of the Ocean Dumping Permit Program (annually since 1973).

9.3.4 Trends in Dredged Materials Dumping

In 1968, the United States dumped approximately 54.9 million tons of dredged material. This figure rose rather slowly until 1973, but took a big jump in 1974 when more than 144.1 million tons were dumped. Total annual quantities decreased since then to the 1977 and 1978 figures of 59.1 and 75.6 million tons, respectively (see Figure 9-3).[13] Future annual totals are not expected to fall lower than this general range because of the continual need for maintenence dredging of many harbor areas. However, it should be noted that annual figures for dredged material dumping can easily fluctuate. Variable weather conditions and large scale flooding in the Mississippi River drainage area, for example, can have a significant effect on the total tons of material dredged in the United States.

The total annual quantities of dredged material will probably increase slightly between 1980 and 2000, with large year-to-year fluctuations. However, this trend could be reversed if the United States were to take advantage of potential alternative uses of dredged materials such as landfill for wetland restoration and artificial island construction, and as a component of building and paving materials. Recent increased efforts by the U.S. Department of Agriculture Soil Conservation Service to reduce soil runoff by encouraging shifts in land use practices should decrease the amount of dredging required.

9.3.5 Ocean Disposal of Radioactive Wastes

While such countries as Belgium, the Netherlands, Switzerland, and the United Kingdom are dumping low-level radioactive wastes in the Northeast Atlantic, the United States does not now dispose of any radioactive wastes in the oceans. The disposal practices of foreign countries are nevertheless a matter of concern in light of recent data indicating a trend toward increasingly radioactive materials. As Table 9-3 shows, while the total weight of dumped materials has remained relatively constant, the radioactivity as measured by alpha radiation from long-lived actinide isotopes has been gradually increasing.[14]

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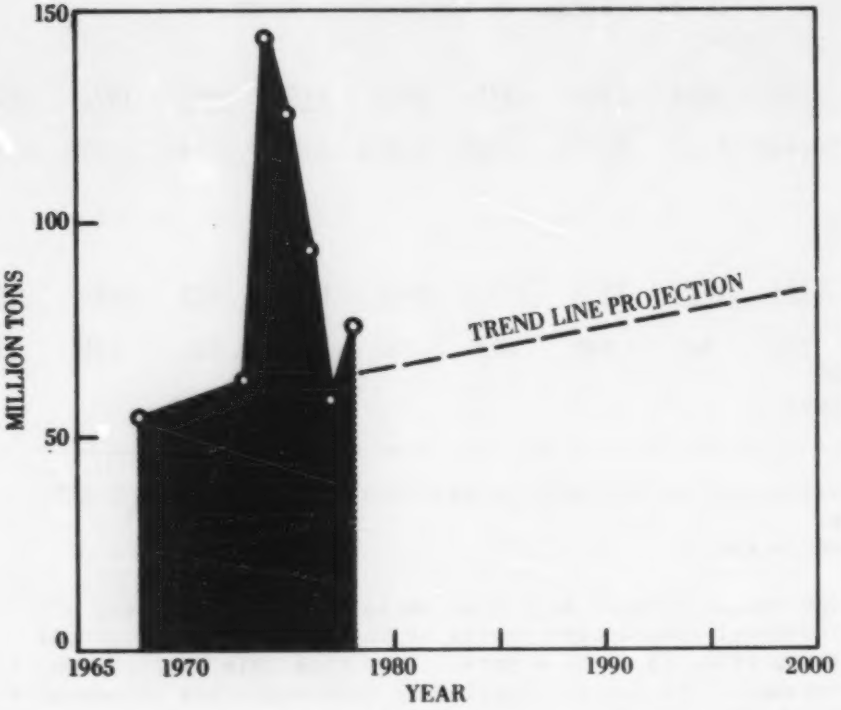
[13] Council on Environmental Quality, Ocean Dumping: A National Policy, October 1970, p. 8. Also, U.S. Environmental Protection Agency, Annual Report on Administration of the Ocean Dumping Permit Program (annually since 1973). Also, personal communication, Army Corps of Engineers.

[14] Council on Environmental Quality, Environmental Quality: The Tenth Annual Report, Washington, D.C., Government Printing Office, 1980, p. 623.



* Data converted from cubic yards to tons, at 1.43 tons per cubic yard.

Source: Council on Environmental Quality, Ocean Dumping: A National Policy, October 1970, and U.S. Environmental Protection Agency, Annual Report on Administration of the Ocean Dumping Permit Program, first through sixth editions.

FIGURE 9-3
TRENDS IN OCEAN DUMPING OF DREDGED MATERIAL
1968-2000

TABLE 9-3
OCEAN DISPOSAL OF RADIOACTIVE WASTES[a]

	1967	1969	1971	1972	1973	1974	1975	1976	1977
Dumped Weight (Metric Tons)	10,840	9,180	3,970	4,130	4,350	2,270	4,460	6,770	5,605

	1967	1969	1971	1972	1973	1974	1975	1976	1977
Alpha Activity[b] (actinides)	250	500	630	680	740	420	780	880	958

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[a] By Organization for Economic Cooperation and Development (OECD) members.

[b] measured in curies

Note: One should keep in mind that while the ocean disposal of low-level radioactive wastes by the U.S. has not occurred since 1970, there is a possibility that this practice could be resumed. The Nuclear Regulatory Commission has recommended further study of ocean disposal of low-level radioactive wastes.[c] The Federal Interagency Task Force on Nuclear Waste Management in its March 1979 report to the President mentioned ocean disposal and burial in accordance with EPA regulations as nuclear waste disposal options.[d]

[c] U.S. Nuclear Regulatory Commission, Screening of Alternative Methods for the Disposal of Low-Level Radioactive Wastes, NUREG/CR-0308, U C209/02 (Washington, D.C., October 1978), pp. 30-32.

[d] Report to the President by the Interagency Review Group on Nuclear Waste Management, Document No. TID-29442, March 1979.

Source: Organization for Economic Cooperation and Development, Activity Reports of the European Nuclear Energy Agency, Nos. 9-13 (Paris:OECD, 1967-71); Activity Reports of the Nuclear Energy Agency, Nos. 1-6 (Paris:OECD/NEA, 1972-1977)

9.4 OCEAN DISCHARGES

9.4.1 Environmental Effects

Two other major sources of ocean pollution are municipal and industrial outfalls. These outfalls present problems in that they discharge biostimulating nutrients, organic chemicals, toxic heavy metals, and microbial pollutants into the marine ecosystem. These discharges are frequently released in coastal and estuarine areas that are particularly sensitive to chemical changes in the environment.

9.4.2 Regulatory Mandates

Ocean outfalls are regulated by Sections 301 and 403 of the Clean Water Act. Secondary treatment of municipal sewage is normally required prior to discharge through ocean outfalls. However, a number of municipalities are being considered for special permits allowing the discharge of waste which has received less than secondary treatment. Modified permits will be issued only if the discharger meets several statutory criteria designed to ensure that the modification will not increase the discharge of toxic pollutants or damage indigenous biological populations.

9.4.3 Trends in Ocean Discharges

A trend in the discharge of waste from outfalls is difficult to determine due to uncertainties in the data on the number and location of these sources of marine pollution. Approximately 2 billion gallons per day are presently discharged directly into the ocean from about 1,970 municipal and 80 industrial outfalls. (These figures do not include a far greater number of outfalls that discharge somewhat smaller volumes of waste into bays and saline estuaries of the United States.) More than half of this national total daily discharge results from four California outfalls.[15] Many, if not most, municipal ocean outfalls have less than secondary treatment.

EPA is in the process of developing outfall regulations under authority of Section 301(b) and 403(c) of the Clean Water Act. The regulations, if adopted, will apply to municipal and industrial facilities. What impact these regulations will have on the total volume of materials discharged through ocean outfalls cannot be determined at this time; however, secondary treatment requirements will dramatically improve the quality of wastes being discharged over the next 10 years.

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[15] U.S. Environmental Protection Agency, Workshop on National Needs and Priorities for Ocean Pollution Research and Development and Monitoring, EPA-600/8-79-012, Tysons Corner, Virginia, November 14-16, 1978, p. 38.

9.5 OTHER ISSUES

Numerous other issues related to the adverse impact of human activities on the marine environment deserve attention. Three of these issues are effects of coal and nuclear power generation facilities, deep sea mining, and toxic chemicals.

9.5.1 Power Generation Facilities

A typical coastal 1,000 megawatt nuclear power plant entrains about a million gallons of seawater per minute.[16] Numerous small organisms such as phytoplankton, zooplankton, fish eggs, and various species of larvae pass through the cooling system along with the cooling water. During their journey through the system these planktonic organisms encounter currents, filters, screens, pumps, chemicals, and heated water, all of which place considerable stress on the organism. Larger fish may be impinged on the intake screens. The ecological balance of marine communities can be altered due to the impacts of these stresses on individual species. Coal-fired power plants, designed to generate electricity through the use of steam, present similar thermal, pollution, impingement, and entrainment problems. The increase in siting of coal and nuclear power plants near or along estuarine and marine environments over the next 20 years will necessitate the development of technologies to reduce the effects on marine life.

In recent years the electric power industry has developed technologies which allow the siting of power plants at locations which would have previously been environmentally unacceptable. However, much progress is yet to be made. Selective intake technologies must be developed to prevent the passage of economically and ecologically important marine species through the cooling system. Discharge technologies must be improved to allow the direct atmospheric ejection of heat, and alternative energy proceses utilizing waste heat, such as cogeneration, should be evaluated.

9.5.2 Deep Sea Mining

International debate over deep sea mining jurisdiction is presently blocking the large scale extraction of such minerals as manganese, copper, cobalt, and nickel. World reserves of exploitable marine mineral deposits are on the order of 1.7 trillion metric tons.[17] It appears that sooner or later these resources will be mined. Evaluations as to how these activities will affect the marine environment are now under way. Researchers are examining possible effects on marine life due to such impacts as siltation of habitats and destruction of benthic food supplies. It is important to evaluate the effects of deep sea mining on the marine environment before embarking on such a program.

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[16] Calculated from Carpenter, E.J., "Power Plant Entrainment of Aquatic Organisms," Oceanus Magazine: Marine Pollution, Fall 1974, p. 35.

9.5.3 Toxic Chemicals

With the dramatic increase in the development of synthetic organic chemicals since World War II, comes a new threat to the marine environment. A significant number of the 7,000 organic and inorganic chemical substances now in commerce may adversely affect marine organisms and even have mutagenic or carcinogenic effects on humans through food chains.[18] The various mechanisms by which these chemicals are transported into and through the ocean are not well understood. Numerous biological, chemical and physical factors influence the fate of toxics. Accurate predictions as to what quantities of chemical pollutants may enter the ocean without long-term adverse effects cannot be made until the transport and fate of these substances are better understood.

The need to understand these processes becomes clear when some of the implications of today's oil crisis are understood. Substitutions in the chemical industry as petrochemical feedstock supplies decline, or as new products are developed, will alter the mix of chemicals released. A basic understanding of relative toxicity and the significance of these new chemical wastes in terms of ecosystem effects is essential to the establishment of a regulatory framework for protecting coastal waters from toxic wastes.

9.6 SUMMARY AND IMPLICATIONS

Pollution of the marine environment from ocean dumping and discharge is expected to decrease significantly during the next 20 years. This trend is due primarily to the anticipated effectiveness of environmental controls either now in effect or pending. For example, the practice of dumping industrial wastes in the Pacific Ocean and Gulf of Mexico has already been effectively eliminated; and dumping sewage sludge is expected to be greatly curtailed by 1981. However, unless new disposal methods or uses are discovered and/or required, the practice of dumping dredged materials will probably continue at about present levels.

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[17] U.S. Environmental Protection Agency, Workshop on National Needs and Priorities for Ocean Pollution Research and Development and Monitoring, EPA-600/8-79-012, Tysons Corner, Virginia, November 14-16, 1978, p. 38.

[18] U.S. EPA, Office of Research and Development, Research Outlook 1979, EPA-600/9-005, U.S. Government Printing Office, Washington, D.C., February 1979, p. 3.

On the other hand, pollution of the marine environment due to oil spills is expected to increase during the next 20 years. This trend is due primarily to forecast increases in offshore oil and gas production and transportation of oil by tankers. That is, the rate of oil spills from these sources is not expected to vary significantly from the historical trends described in this chapter. Rather, it is the increase in activity and, therefore, increased opportunities for accidents that lead to a forecast of increased marine pollution from oil spills.

Although generally not discussed in this chapter, the trends in point and non-point water pollutants, discussed in Chapter 6, have important marine pollution implications. In particular, trends in the agricultural runoff, and oil and grease categories can have significant impact on the marine environment. Both are sources of the toxic substances discussed above as well as the conventional pollutants discussed in Chapter 6. As point sources are controlled more effectively, non-point sources, such as municipal and agricultural runoff, will contribute a larger percentage to water pollution problems generally, including problems in the marine environment. Based on the findings in Chapter 6, the overall national trend is expected to be an increase in the annual discharge of pollutants in the non-point category. These include agricultural runoff, which is a major source of nutrients, and toxics, pesticides, and acids, all of which can cause marine pollution problems, particularly in critical ecosystems in the coastal zones.

Another pollutant of particular concern for the marine environment is refined oil and grease. As discussed in Chapter 6, this category of pollutants comprises thousands of organic compounds, many of which are toxic to aquatic organisms. If non-marine operations continue to be the source of more oil pollution than marine operations or even a major source, as some studies project, future trends in the introduction of oil into the marine environment will depend in large part on controlling the release or discharge of oil and grease from these non-marine sources.[19] The trends projected in Chapter 6 show an expected decline in oil and grease discharges nationally. However, increased discharges are projected for the Northwest Region (Federal Region X).

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[19] The most recent statistics are from two studies published in 1970 and 1971: Massachusetts Institute of Technology, Man's Impact on the Global Environment, Report of the Study of Critical Environmental Problems (SCEP), Cambridge, Massachusetts, MIT Press, 1970; and National Academy of Sciences, Marine Environmental Quality, Washington, D.C., 1971.

CHAPTER 10
SOLID AND HAZARDOUS WASTES

HIGHLIGHTS OF CHAPTER 10

- Ensuring the safe disposal of hazardous wastes and identifying and containing existing active and abandoned disposal sites is one of the most critical problems currently facing EPA.
- Annual generation of all types of solid wastes studied is expected to at least double and maybe triple between 1975 and 2000. In most cases recycling is not expected to offset these increases.
- As annual disposal requirements increase, the problems of solid waste disposal, particularly land-related problems, may become severe in some areas.
- Inadequate disposal of solid wastes has been shown to be a major cause of ground water contamination. In some areas drinking water supplies have been contaminated in this fashion.

10.1 INTRODUCTION

10.1.1 Problem Identification and Regulatory Background

The need for better disposal of solid and liquid wastes, especially hazardous wastes, is getting increasing attention nationwide. The United States generates some 4 billion tons of solid waste every year according to EPA's Office of Solid Waste (OSW), which estimates industrial wastes at 380 million tons, municipal refuse at 145 million tons, sewage sludge at 5.5 million tons, agricultural wastes at 475 million tons, and mining wastes at 3 billion tons.[1] Much of this waste is discarded on land, polluting air and water, creating health hazards, and degrading surrounding areas. Furthermore, OSW estimates that this mass of waste material includes 33 to 44 million tons of hazardous wastes, much of it disposed of in haphazard fashion.[2]

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[1] U.S. Environmental Protection Agency, Office of Water and Waste Management, EPA Activities Under the Resource Conservation and Recovery Act: Fiscal Year 1978, SW-755, Washington, D.C., March 1979, pp. 1-2.

[2] U.S. Environmental Protection Agency, Office of Public Awareness, "Hazardous Waste Fact Sheet," EPA Journal: Waste Alert, Vol. 5, Washington, D.C., February 1979, p. 12.

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EPA has developed a general approach in recent years to address the solid waste problem. This approach has three parts. First, the quantity of solid waste generated annually should be reduced. This could be accomplished by waste reduction techniques, such as increasing product durability or changing production techniques. Second, whenever possible, solid waste should be used as a source of materials and energy. This would involve expanding the use of recycling and resource recovery. Third, whatever solid waste is generated and cannot be reused must be disposed of in a manner that is safe for human health and the environment.

This chapter examines the trends in the generation and disposal of the major types of solid waste. Overall solid waste generation is increasing. Recycling and resource recovery are expected to partly offset the increases expected, but only expanded use of waste reduction techniques, particularly within industry, can lessen or reverse the expected annual increase in generation of wastes. Meanwhile, the wastes that are not amenable to waste reduction or recycling techniques must be disposed of safely.

The three-part approach described is embodied in the Resource Conservation and Recovery Act (RCRA) passed in 1976. This Act, which amended Title II of the Solid Waste Disposal Act[3] is designed to "promote the protection of health and the environment and to conserve valuable material and energy resources."[4] In RCRA, Congress has defined solid wastes as

> Any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semisolid or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations and from community activities.[5]

Specifically not included in this definition are

> Solid or dissolved material in irrigation return flows or industrial discharges subject to permits under Section 402 of the Federal Water Pollution Control Act ... or source,

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[3] The Solid Waste Disposal Act, 42 U.S.C. 3251 et seq.

[4] The Resource Conservation and Recovery Act, PL 94-580, Section 1003.

[5] The Resource Conservation and Recovery Act, PL 94-580 as amended by the Quiet Communities Act of 1978; Section 1004 (27).

> special nuclear, or byproduct material defined by the Atomic Energy Act....[6]

This definition of solid waste will be used throughout the chapter except where specialized treatment is necessary.[7]

Three of the eight RCRA sections embody most of the regulatory provisions:

Subtitle A:	General Provisions
Subtitle C:	Hazardous Wastes
Subtitle D:	State or Regional Solid Waste Plans

Subtitle A requires EPA to publish suggested guidelines for solid waste management. Subtitle C requires EPA to promulgate regulations concerning hazardous wastes for the purpose of monitoring and controlling such wastes from the point of generation to ultimate disposal--"from the cradle to the grave." This portion also defines what is meant by a hazardous waste. The objective of Subtitle D is to "assist in developing and encouraging methods for the disposal of solid wastes which are environmentally sound and which maximize the resource conservation."[8] To work toward this objective, state or regional authorities must submit plans to EPA for approval.

EPA has not as yet promulgated final regulations under any of these sections. The status of the regulations as of May 15, 1979 is summarized in Table 10-1.

Many laws and regulations beside RCRA affect solid waste generation and disposal. These include the Clean Air Act and the Clean Water Act, which will be discussed where appropriate in this chapter and in other chapters.

10.1.2 Relevant Scenario Assumptions

The projections for the various types of solid waste discussed in this chapter are not based on a single set of scenario assumptions, but are taken from numerous individual analyses. Each of Sections 10.3, 10.4, 10.5, and 10.6 is based wholly or in part on SEAS projections. However, the projections used are not all the result of the same scenario. Therefore, each section will either discuss the

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[6] The Resource Conservation and Recovery Act, PL 94-580 as amended by the Quiet Communities Act of 1978; Section 1004 (27).

[7] This caveat applies to Section 10.3 in particular. Specific definitions will be provided in this section.

[8] The Resource Conservation and Recovery Act, PL 94-580, Section 4001.

TABLE 10-1
RCRA REGULATIONS AND GUIDELINES ISSUED OR IN PREPARATION AS OF MAY 15, 1979[a]

Section of the Act	Description	Status
1008	Solid waste management guidelines	Proposed guidelines on landfill disposal scheduled for March 1979 with final in January 1980
3001	Identification and listing of hazardous waste	Proposed December 18, 1978 Final scheduled for May 1980
3002	Standards for generators of hazardous waste	Proposed December 18, 1979 Final scheduled for February 1980
3003	Standards for transporters of hazardous waste	Proposed April 28, 1978 Final scheduled for February 1980
3004	Standards for hazardous waste treatment, storage, and disposal facilities	Proposed December 18, 1978 Final scheduled for April 1980
3005	Permits for treatment, storage, or disposal of hazardous waste	Proposed June 14, 1979 Final scheduled for April 1980
3006	Guidelines for development of state hazardous waste programs	Proposed February 1, 1978 Reproposed June 14, 1979 Final scheduled for April 1980
3010	Notification system regulations	Proposed July 11, 1978 Final scheduled for February 1980
4002(a)	Guidelines for identification of regions and agencies for solid waste management	Interim guidelines published May 16, 1977
4002(b)	Guidelines for state plans	Proposed August 28, 1978 Final published in July 1979

(Continued)

TABLE 10-1 CONCLUDED
RCRA REGULATIONS AND GUIDELINES ISSUED OR IN PREPARATION AS OF MAY 15, 1979

Section of the Act	Description	Status
4004	Criteria for classification of disposal facilities	Proposed February 6, 1978 Final published in September 1979
4005	Open dump survey	Awaiting 4004 criteria
8002	Special studies	
	Composition of Waste Stream	Current
	Priorities Study	Current
	Small-scale and Low Technology	Current
	Front-end Source Separation	Current
	Mining Waste	FY 1979
	Sludge	FY 1979
	Glass and Plastic	Start FY 1978
	Tires	Start FY 1978
	Resource Recovery Facilities	Start FY 1978
	Resource Conservation Committee	
	Beverage Bottle Study	FY 1979
	Disposal Charge Study	Current

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[a] This list reflects the status of the RCRA guidelines and regulations as of May 15, 1979. As of the date of publication of the 1980 Environmental Outlook, few if any of the deadlines for promulgation given here are expected to be met.

relevant scenario assumptions or refer to a discussion of the scenarios on which the projections are based. In each case, these projections are used as indicators of general trends rather than precise forecasts.

10.1.3 Data Sources and Quality

The data sources used in preparing this chapter vary considerably. Because of this, no attempt will be made here to analyze the sources as a group. The data sources used in each section are referenced in the appropriate sections. Discussions of the data quality for the SEAS-based sections (Sections 10.4.3 and 10.5) are included in those sections.

10.1.4 Organization of Chapter

Five types of solid wastes are discussed in the following sections: hazardous wastes, municipal and industrial solid wastes, mining and related wastes, and secondary wastes arising from pollution controls. An additional section deals, in less detail, with agricultural wastes and other types of solid wastes not already discussed.

The discussion centers around trends in the generation of these wastes and potential adverse environmental effects. Current, future, and alternative methods of disposal are analyzed in the context of the Resource Conservation and Recovery Act. Implications of these trends and disposal problems are discussed in Section 10.7, followed by summary and conclusions in Section 10.8.

10.2 HAZARDOUS WASTES

HIGHLIGHTS OF SECTION 10.2

- Annual generation of hazardous wastes is expected to double between 1975 and 2000.

- Inadequate disposal of hazardous wastes generated in the past has already had significant adverse human health impacts in some areas. The cost to correct past inadequacies is unknown but may be large. A Federal fund to provide resources to contain existing or abandoned hazardous waste disposal sites has been proposed in Congress.

- Final regulations under the Resource Conservation and Recovery Act to control hazardous wastes are expected by the end of 1979. The total cost to industry of implementing the regulations has been estimated by EPA at more than $750 million annually.

10.2.1 Introduction

Congress, in the Resource Conservation and Recovery Act, has defined hazardous wastes as

> a solid waste, or combination of solid wastes which, because of its quantity, concentration, physical, chemical, or infectious characteristics may
>
> (A) cause, or significantly contribute to an increase in mortality or an increase in serious irreversible or incapacitating reversible illness; or
>
> (B) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, as otherwise managed.[9]

To summarize: Hazardous wastes are those that pose a significant threat to human health or the environment during any phase of the waste's existence.

From 10 to 15 percent of the 380 million tons (wet weight) of industrial waste produced annually in the United States is hazardous, according to EPA estimates. EPA has identified 17 industry groups that produce 38 million tons (wet) of hazardous waste.[10] Sixty-five percent of these wastes are generated in Texas, Ohio, Pennsylvania, Louisiana, Michigan, Indiana, Illinois, Tennessee, West Virginia, and California (see Table 10-2).[11]

Much of this waste is currently disposed of in a manner not consistent with proposed regulations for the hazardous wastes studied. It has been estimated that 50 percent of all hazardous waste is disposed of in unlined surface lagoons, 30 percent goes into non-secure landfills, and 10 percent is either spread on roads, dumped into sewers, incinerated under uncontrolled conditions, or injected into deep wells. Therefore, only 10 percent of all hazardous waste is disposed of safely.[12]

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[9] The Resource Conservation and Recovery Act, PL 94-580, Section 4001.

[10] U.S. Environmental Protection Agency, Office of Public Awareness, "Hazardous Waste Fact Sheet," EPA Journal:Waste Alert, Vol. 5, Washington, D.C., February 1979, p. 12.

[11] Ibid.

[12] Maugh, T.H. II, "Toxic Waste Disposal: A Growing Problem," Science, Vol. 204, May 25, 1979, p. 819.

TABLE 10-2
GENERATION OF HAZARDOUS WASTE BY SELECTED INDUSTRIES
1977

Industry Group	Waste (10^6 tons, wet)
Organic Chemicals	12.9
Primary Metals	9.9
Electroplating	4.5
Inorganic Chemicals	4.4
Textiles	2.1
Petroleum Refining	2.0
Rubber and Plastics	1.1
Miscellaneous (7 Industries)	1.1
Total	38.0

Source: U.S. Environmental Protection Agency, "Hazardous Waste Fact Sheet," EPA Journal: Waste Alert, Vol. 5, Washington, D.C., February, 1979.

The greater portion (70 to 80 percent) of all hazardous waste is disposed of on-site. The remaining portion is handled by commercial disposal companies.

It is currently estimated that industrial waste generation is increasing at a rate of 3 percent per year.[13] If this trend continues and hazardous waste continues to represent 10 to 15 percent of the industrial waste total, annual hazardous waste generation would exceed 75 million tons (wet) by 2000.

Two distinct problems are posed by the generation and disposal of these wastes: First, what is to be done about existing abandoned disposal sites that contain hazardous wastes stored without adequate precautions? Second, how are we to cope with future generation of hazardous waste? The following discussion treats each of these aspects separately.

10.2.2 Existing Disposal Sites

In 1978, a major health disaster caused by inadequate disposal of hazardous waste first came to national attention. Numerous chemicals were found to be leaching from an abandoned dumpsite along the Love Canal in Niagara Falls, New York. These chemicals were found in the basements and yards of the houses surrounding the dumpsite. Air samples taken in and around the houses indicated the presence of several dangerous chemicals. More than 20,000 tons of chemical wastes had been placed in the site 25 years ago by the Hooker Chemical Company. There is evidence that 300 different chemicals are present in the dumpsite; 100 have been identified, and include 11 suspected carcinogens and one known carcinogen, benzene. David Axelrod, New York State Health Commissioner, has estimated that possibly 10 percent of the chemicals in the dumpsite may be mutagens, teratogens, and carcinogens.[14]

The possibility of the presence of such agents is supported by health statistics of the people living in the area. The incidence of miscarriages in young women living in certain areas around the canal was three times the normal rate. The incidence of birth defects in children born to parents living in the area was 3.5 times the normal rate. Many of the adults living in the area have shown signs of liver damage.[15] Whereas these statistics are preliminary and subject to sampling problems, it is safe to say that the incidences of these health problems are elevated near the Love Canal.[16]

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[13] U.S. Environmental Protection Agency, Office of Public Awareness, Solid Waste Facts: A Statistical Handbook, OPA-113/8, August 1978, p. 2.

[14] Maugh, T.H. II, "An Environmental Time Bomb Gone Off," Science, Vol. 204, May 25, 1979, pp. 820-823.

Measures have been taken to seal off the area around the dumpsite. In August 1978 the Love Canal area was declared eligible for Federal disaster relief funds. The total cost to clean up the site has been estimated at $30 million.[17] Lawsuits involving $2 billion are currently in progress.

This disaster graphically illustrates the dangers we now face because of past inadequacies in disposing of hazardous wastes. Further, more than 300 additional incidents involving hazardous wastes have been reported to EPA.[18] It must be stressed, however, that in many cases--Love Canal as an example--the disposal methods used complied with the regulations existing at the time.

EPA has identified 151 sites in the United States that pose a potential threat to human health or the environment due to the presence of hazardous wastes (see Figure 10-1).[19] These include Kin Buck landfill in New Jersey, the "Valley of the Drums" in Kentucky, and numerous on-site disposal areas such as the chemical dumpsite near White Lake, Michigan.[20] This list of sites is under continuous review and new sites are being added to the list periodically. One estimate prepared for OSW indicates that as many as 32,000 active or abandoned dump sites may contain hazardous wastes, with more than 800 containing significant quantities of such wastes. This estimate was based on a survey of EPA regions. Use of an alternative method based on the quantity of hazardous waste generated annually resulted in an estimate of more than 50,000 active and inactive hazardous waste

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[15] Maugh, T.H. II, "An Environmental Time Bomb Gone Off," Science, Vol. 204, May 25, 1979, pp. 820-823. Further epidemiological studies, all producing different quantitative results, do not dispute the conclusions of increased incidences of the health problems noted in the Love Canal area.

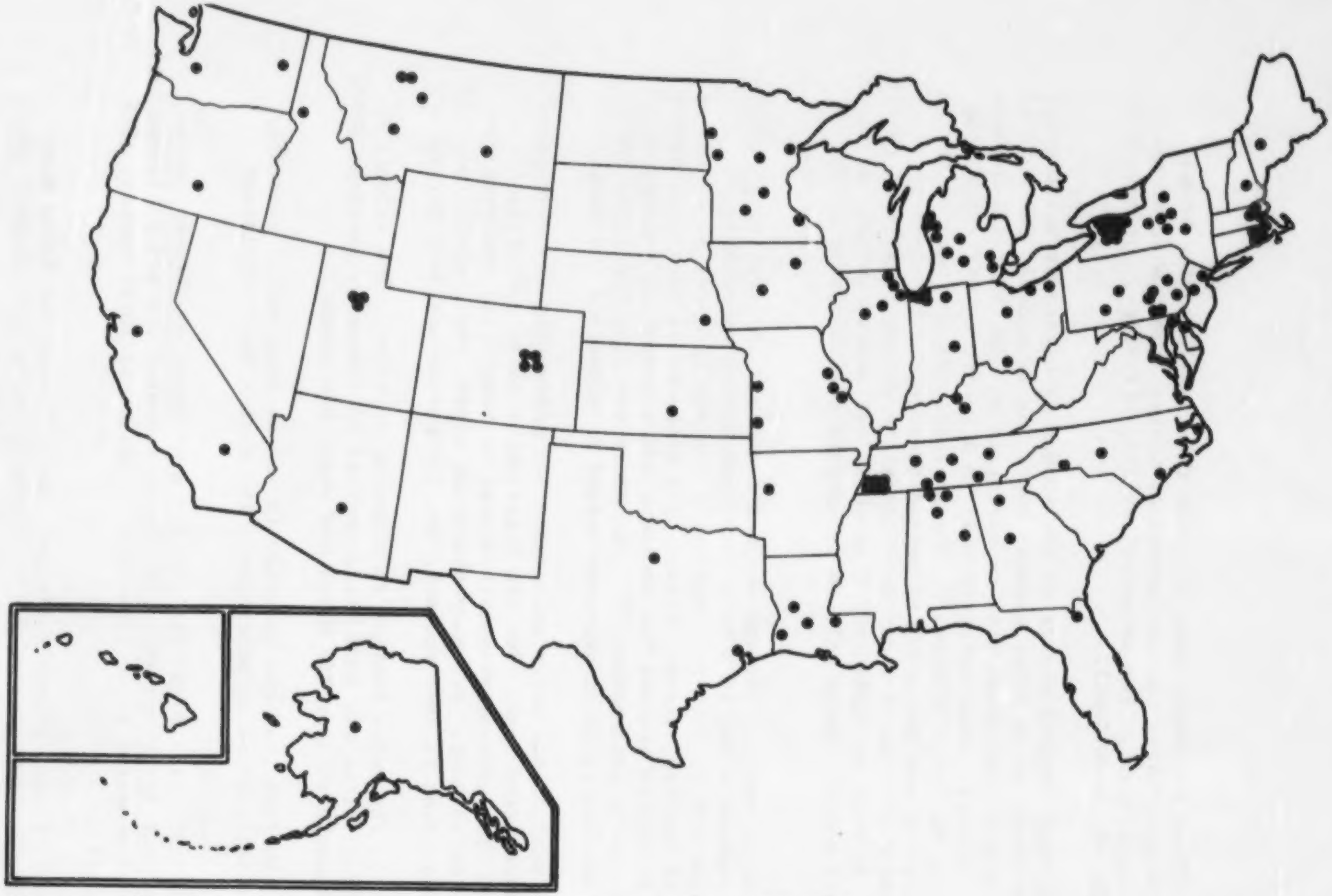
[16] Personal communication, Glenn E. Haughie, M.D., Department of Health, State of New York, July 1979.

[17] Maugh, T.H. II, "An Environmental Time Bomb Gone Off," Science, Vol. 204, May 25, 1979, pp. 820-823.

[18] U.S. Environmental Protection Agency, Subtitle C, Resource Conservation and Recovery Act of 1976 Draft Environmental Impact Statement Appendices, Appendix J, January 1979, p. J-1.

[19] U.S. Environmental Protection Agency, Revised Status Report - Hazardous Waste Sites, June 1, 1979.

[20] Maugh, T.H. II, "Toxic Waste Disposal: A Growing Problem," Science, Vol. 204, May 25, 1979, p. 822.



Source: Based on U.S. Environmental Protection Agency, Revised Status Report-Hazardous Waste Sites, June 1, 1979.

FIGURE 10-1
IDENTIFIED HAZARDOUS WASTE SITES

sites.[21] These estimates make it clear that, while no one knows exactly how many sites contain hazardous wastes, the number of such sites is significant. The potential exists, therefore, for more disasters like the Love Canal.

Along with uncertainty as to the number of hazardous waste sites goes uncertainty as to total cleanup cost. As mentioned, the cost of cleaning up the Love Canal site is estimated at more than $30 million. Estimates of total clean-up costs made in a report to OSW range from $3.6 billion to $44.1 billion.[22] The estimates depend both on the number of sites and the level of treatment required to clean up a site. Cost estimates on a per site basis range from $4 million to $26 million. It must be emphasized that these estimates, because of their preliminary nature, serve only to illustrate the magnitude of the costs.

The major vehicle through which EPA can aid in cleaning up existing or abandoned sites is RCRA's "imminent hazard" provision,[23] which allows EPA to file suit against a company to force it to change the ways it handles, stores, treats, and disposes of hazardous wastes if these practices present "an imminent and substantial endangerment to health or the environment."[24] The court may also force the company to take any remedial measures needed to alleviate the danger.

This section has major weaknesses for addressing the widespread problem identified here. For the legislation to be effective for a given site, the company responsible must be identified and that company must be solvent. For many abandoned sites, these conditions cannot be met. Even if they are met, the litigation may last for years.

Cost is the major barrier to cleaning up sites. The situation for abandoned sites has been characterized by Thomas C. Jorling, EPA's Assistant Administrator for Water and Waste Management:

> We find that the question is not so much one of authority, legislative or otherwise. The states have sufficient

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[21] Fred C. Hart Associates, Preliminary Assessment of Cleanup Costs for National Hazardous Waste Problems, prepared for and published by U.S. Environmental Protection Agency, Office of Solid Wastes, 1979, pp. 11, 23.

[22] Ibid.

[23] Steffen W. Plehn, Deputy Assistant Administrator for Solid Waste, in interview with Charles Pierce, editor, in "A Look Ahead," EPA Journal: Waste Alert, Vol. 5, February 1979, p. 11.

[24] The Resource Conservation and Recovery Act, PL 94-580, Section 7003.

> authority under their police powers.... Instead, the question is finding the resources to provide a remedy.[25]

To handle this resource problem, President Carter has proposed that the government establish a "Superfund"[26] to provide money to contain existing uncontrolled hazardous waste disposal sites. This $1.6 billion fund, established over four years, would be funded by the Federal government (20 percent) and fees on the industries that generate hazardous wastes (80 percent). According to the proposal,[27] the fund would be used as follows:

- Once a site has been found to be hazardous, an effort will be made to identify the party responsible and ask that the site be cleaned up.

- If the party responsible refuses, or if no responsible party can be found, the Federal government will provide up to $300,000 from the fund in emergency assistance. This money would be used for immediate projects, such as providing an alternative drinking water supply.

- If the state government agrees to cooperate in containing the site and to maintain the site for 19 years after containment, the Federal government, from the fund, will provide 100 percent of the first $200,000 of containment cost, and 90 percent of any containment cost over $200,000. The state government will provide the remaining 10 percent of the containment costs over $200,000 and money to maintain the site for the remaining 19 years of the agreement. The state must also assure that any necessary offsite treatment facilities are available.

- If the disposal site is state-owned, the state must pay 50 percent of any containment costs as well as maintain the site.

- The fund would cover only economic damages and would not cover personal injury, medical costs, or third party damages.

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[25] Thomas C. Jorling, Assistant Administrator for Water and Waste Management, in interview with John Heritage, assistant editor, in "Managing Hazardous Wastes," EPA Journal: Waste Alert, Vol. 5, February 1979, p. 7.

[26] The "Superfund" proposal is contained in the proposed Oil, Hazardous Substances, and Hazardous Waste Response, Liability, and Compensation Act of 1979. See Chapter 9 for more information on the Act itself.

[27] Personal communication, Marc Tipermas, U.S. Environmental Protection Agency, Office of Water and Waste Management, June 25, 1979.

The fund would be maintained, as necessary, to provide resources for containment of hazardous waste disposal sites in the future.

10.2.3 Future Disposal of Hazardous Wastes

Subtitle C of the Resource Conservation and Recovery Act, which deals exclusively with the problem of future hazardous waste management, has three key provisions:

- Identification of hazardous wastes
- Institution of a manifest system to track wastes through their life cycle
- Establishment of a permit system, based on standards for hazardous waste treatment[28]

States may administer the individual hazardous waste management programs if their programs are approved by EPA. Forty-one states are expected to request "interim authorization" to administer their programs.[29]

To implement Section 3001 of Subtitle C of the Act, EPA has tentatively listed eight characteristics of hazardous wastes:

1. Ignitability
2. Corrosivity
3. Reactivity
4. Leachate toxicity
5. Radioactivity
6. Infectiousness
7. Phytotoxicity
8. Teratogenicity and mutagenicity

Proposed regulations defining these characteristics were issued on December 18, 1978.[30] Considerable comment has been received on the definitions and related testing procedures, and the proposed regulations are being reviewed in the light of these comments. Final regulations are not expected before December 1979.

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[28] U.S. Environmental Protection Agency, Office of Water and Waste Management, EPA Activities Under the Resource Conservation and Recovery Act: Fiscal Year 1978, SW-755, Washington, D.C., March 1979, p. 2-1.

[29] U.S. Environmental Protection Agency, Office of Public Awareness, "Hazardous Waste Fact Sheet," EPA Journal: Waste Alert, Vol. 5, Washington, D.C., February 1979, p. 12.

[30] "Hazardous Waste: Proposed Guidelines and Regulations and Proposal on Identification and Listing," Federal Register, December 18, 1979, Part IV, pp. 58946-58959.

Besides specific wastes meeting the hazard criteria outlined in the proposed regulations, EPA has declared numerous classes of wastes as hazardous. However, if a manufacturer can show that the waste he generates in such a class does not violate the criteria for hazard listed in the regulations, that individual waste will be exempted from Subtitle C provisions.

The manifest system outlined in Subtitle C enables EPA to monitor the flow of hazardous wastes in the economy from beginning to end. This system, coupled with the standards for generation (Section 3002); transportation (Section 3003); and treatment, storage, or disposal (Section 3004), serves to ensure that hazardous wastes are handled and disposed of safely on a waste-by-waste basis. Final action on these regulations is also pending.

The proposed regulations establish a category called "special wastes"--hazardous wastes that, because of high generation volumes but relatively low hazard, are not amenable to control techniques developed in Subtitle D.[31] Hence, special wastes will be regulated under a subset of the Subtitle C regulations. Examples of special wastes include utility waste, cement kiln dust, uranium mining wastes (as distinct from mill tailings which are treated as radioactive material), phosphate mining, beneficiation and processing wastes, and gas and oil drilling muds.[32]

While efforts to control hazardous wastes face several major problems, Steffen W. Plehn, EPA's Deputy Assistant Administrator for Solid Waste, has stated "We believe the most difficult long-term problem will be obtaining sites for proper management of these wastes."[33] Citizen opposition to the siting of hazardous wastes disposal facilities in their communities is the core of this problem. Adding to the siting problems are the restrictions on locating disposal facilities in areas that present a danger to the integrity of the facility (e.g., active fault zones) or in which the facility presents a danger to the environment (e.g., wetlands). This problem may be relieved, to some extent, by safe operation of hazardous waste disposal facilities.

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[31] The Resource Conservation and Recovery Act, PL 94-580, Sections 4001-4009.

[32] "Hazardous Waste: Proposed Guidelines and Regulations and Proposal on Identification and Listing," Federal Register, December 18, 1978, Part IV, pp. 59015-59016.

[33] Steffen W. Plehn, Deputy Assistant Administrator for Solid Waste, interview with Charles Pierce, editor, in "A Look Ahead," EPA Journal: Waste Alert, Vol. 5, February 1979, p. 11.

Several treatment techniques are being developed to augment or improve techniques now in use. For example, many wastes can be chemically treated to detoxify the waste. The most common techniques include neutralization or pH adjustment, oxidation and reduction reactions, and volume reduction techniques such as evaporation in a holding pond or vacuum filtration. Less common techniques that could be used include activated carbon adsorption and ion exchange.[34]

Drawing on the experience gained in the disposal of low-level radioactive wastes, many companies are developing solidification techniques to aid in disposing of hazardous wastes. These techniques fall into four basic categories: cement-based techniques, lime-based techniques, thermoplastic techniques, and organic binders.[35] Each of these techniques has only limited applicability and no technique is applicable to all hazardous wastes. Nevertheless, according to Robert Landreth of EPA, at least one solidification process can be selected to handle any waste.[36]

A serious limitation of the chemical and solidification techniques is that they are generally used not for disposal but as preparation processes before landfilling the wastes. In keeping with the spirit of RCRA a program that de-emphasizes land disposal would be preferable because it would avoid the severe problems associated with landfilling, such as lack of available sites, contamination of ground and surface water, and health hazards. EPA emphasizes recycling or exchanging wastes, or altering production processes, where possible, to eliminate hazardous wastes, in keeping with the concept that "land disposal of hazardous waste is the last resort."[37]

To encourage action in the recycling and exchange of hazardous and other wastes, EPA has been promoting the establishment of "waste exchanges." These exchanges are clearinghouses for information on waste products that are available for uses in other processes. Certain European countries have had success with such exchanges, but results in the United States have been limited, primarily because industry has been reluctant to provide information on wastes produced. According to Harry Trask of EPA, state and local efforts to become involved in the waste exchanges have encountered many refusals by industries to provide information, because of a fear that it may fall into what the industry considers to be "unfriendly hands."[38]

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[34] Maugh, T.H. II, "Hazardous Waste Technology Is Available," Science, Vol. 204, June 1, 1979, pp. 930-933.

[35] Maugh, T.H. II, "Burial is Last Resort for Hazardous Wastes," Science, Vol. 204, June 22, 1979, pp. 1295-1298.

[36] Ibid.

[37] Steffen W. Plehn, Deputy Assistant Administrator for Solid Waste, interview with Charles Pierce, editor, in "A Look Ahead," EPA Journal: Waste Alert, Vol. 5, February 1979, p. 11.

Possibilities for direct reuse of hazardous wastes are also being investigated in some industries. This involves removing from the wastestream materials that, on occasion, are hazardous, and reusing them in the original production process. In many cases these procedures serve to reduce both the hazard and the volume of the wastes ultimately generated.

For many hazardous wastes, controlled incineration presents a technically feasible and environmentally safe method of disposal which is particularly applicable for organic wastes. Several companies, including Dow Chemical Company, Eastman Kodak, and 3M Corporation, are disposing of hazardous wastes through high-temperature chemical waste incineration. The high temperatures are required to break down many hazardous compounds.[39] The United States Air Force has used ocean-going high-temperature incineration to destroy toxic chemicals.[40] It is likely, therefore, that an increasing amount of hazardous waste could be incinerated.

Several factors restrict the use of high temperature hazardous waste incineration. These include relatively high cost, lack of effective measures to control the release of hazardous by-products of incineration into the atmosphere, and the poor combustion properties of many wastes. Local resistance to siting land-based incinerators is also a major problem. High temperature incinceration is a very promising disposal alternative, but it is not a panacea.

Deep wells have been used for many years to dispose of hazardous liquid wastes and may be used to dispose of many such wastes in the future. Regulations to control deep well injection of hazardous wastes have been promulgated under the Safe Drinking Water Act. These regulations and the possible effects of deep well injection are discussed in Chapter 7.

For many hazardous wastes, particularly nonchlorinated organic wastes, land farming or soil incorporation is an acceptable alternative. The petroleum refining industry has had marked success for years in disposing of refinery sludge in this manner.[41] EPA has proposed regulations for land farming, including requirements on heavy metals content and pH.[42]

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[38] Maugh, T.H. II, "Hazardous Waste Technology Is Available," Science, Vol. 204, June 1, 1979, pp. 930-933.

[39] Perham, C., "Industrial Incineration," EPA Journal: Waste Alert, Vol. 5, February 1979, pp. 21, 40.

[40] Whiteside, T., The Pendulum and the Toxic Cloud: The Course of Dioxin Contamination, Yale University Press, New Haven, Connecticut, 1979.

In any event, short-term possibilities for recycling and exchange of hazardous wastes are limited. Since process changes to eliminate hazardous waste products are in many cases infeasible or impossible at this time, treatment and land disposal would appear to be the major hazardous waste disposal options available, at least in the near future.

The major non-environmental effect of the proposed RCRA regulations will be to increase the cost of disposal. Since disposal in a landfill may cost as little as $5 per ton, while acceptable alternatives may cost as much as $300 per ton, the increased cost to industry could be significant.[43] Many of the alternatives, however, will become more competitive as the cost of landfill disposal increases. EPA has estimated that the cost of RCRA regulations in the 17 industries studied would be $750 million annually; the industry responded with an estimate that the cost would be $25 billion.[44] Whatever these costs may be, complying with final RCRA regulations will probably cost less than cleaning up the existing hazardous waste dumpsites, and almost certainly less than the total cost to industry of damage suits brought by the victims of incidents such as the Love Canal.

10.3 MUNICIPAL AND INDUSTRIAL SOLID WASTES

HIGHLIGHTS OF SECTION 10.3

- Under the assumption that current trends in recycling, materials substitution, and economic growth will continue, the annual disposal requirements for both municipal and industrial solid wastes are expected to increase between 1975 and 1990.
- Most municipal and industrial solid wastes are disposed of on land. However, numerous options are either available or under

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[41] Maugh, T.H. II, "Hazardous Waste Technology Is Available," Science, Vol. 204, June 1, 1979, pp. 930-933.

[42] "Hazardous Waste: Proposed Guidelines and Regulations and Proposal on Identification and Listing," Federal Register, Part IV, December 18, 1979, pp. 59013-59014.

[43] Maugh, T.H. II, "Toxic Waste Disposal: A Growing Problem," Science, Vol. 204, May 25, 1979, p. 819.

[44] Maugh, T.H. II, "An Environmental Time Bomb Gone Off," Science, Vol. 204, May 25, 1979, pp. 820-823.

study to aid in municipal and industrial waste reduction and recycling as alternatives to land disposal.

10.3.1 Introduction

The disposal of municipal and industrial solid wastes is becoming more and more difficult in many urban areas. In the past, land disposal and ocean dumping have been the major disposal methods. However, land values are increasing and ocean dumping is to be banned in 1981, so municipalities and industries are being forced to find alternative disposal methods.

The following discussion focuses on the projected generation and disposal options for municipal and industrial solid wastes, treating each type of waste separately. The environmental impacts of the recycling of municipal solid waste are addressed in Section 10.7.

10.3.2 Industrial Solid Wastes

Various estimates of annual industrial solid waste generation differ substantially. Much of this apparent uncertainty is due to differences in the definitions of industrial solid wastes used in the studies, and the categories included or excluded. For the purposes of this analysis, industrial solid waste is defined as non-product "solid" material resulting from the production of industrial goods; specifically excluded are sludges, ash, and liquid wastes[45] covered in the basic "solid waste" definition in Section 10.1.

Using a specially designed SEAS module, the International Research and Technology Corporation (IR&T) has developed a projection of annual net[46] industrial solid waste generation.[47] This figure was produced under a scenario which assumes continuation of past and current trends in recycling, materials substitution, and economic growth.[48]

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[45] International Research and Technology Corporation, Forecasts of the Quantity and Composition of Solid Waste, IRT-19300/R-3, June 1979, p. 15.

[46] In keeping with general terminology of SEAS, "net" solid wastes refers to the amount of solid waste generated minus the amount of waste recovered.

[47] International Research and Technology Corporation, Forecasts of the Quantity and Composition of Solid Waste, IRT-19300/R-3, June 1979. The scenarios developed by IR&T and used in this section are not related to the High Growth and Low Growth Scenarios used elsewhere.

[48] Ibid, p. 23.

The IR&T projections of net industrial solid waste generation in 1971, 1980, and 1990 are presented in Table 10-3. According to these projections, the annual requirement for disposing of industrial solid wastes would show only moderate growth, increasing from 14 million tons in 1971 to 18 million tons in 1990. If the projected trend were to continue to 2000, annual generation of industrial solid waste would reach about 20 million tons.[49]

Current industrial trends toward recycling and substituting materials would serve to decrease the annual requirement for disposing of these wastes. However, the IR&T projections indicate that these trends will not offset the increases in solid wastes due to the higher industrial production that would be expected in a healthy economy (3.4 percent average annual growth in GNP).

Aside from direct recycling and materials substitution, another major option for handling industrial solid wastes is that of industrial waste exchanges. Two types of exchanges are functioning. The first is basically an information exchange or clearinghouse. It operates by providing information to a company on waste products that are available and by putting that company in contact with other firms which have wastes that the company can use or which can use wastes the company generates. The second type is a materials exchange, which buys waste from one company and sells it to another. There are numerous variations and combinations of these basic types of exchanges.[50]

As mentioned in Section 10.2.3, waste exchanges have met with varying success in this country. Fourteen information exchanges and three materials exchanges currently exist in the United States,[51] and have considerable potential for reducing industrial solid waste disposal requirements. However, many of the exchanges established in the early 1970s are no longer operating. The major problem apparently was uncertainty on the part of industry as to whether information provided to the exchanges would remain confidential.

10.3.3 Municipal Solid Wastes

The different materials in municipal solid waste (MSW) are usually classified into three categories: post-consumer solid wastes (both residential and commercial), food wastes, and yard wastes.

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[49] This figure is a simplistic extrapolation of the projected trend and is provided for comparative purposes only.

[50] U.S. Environmental Protection Agency, Industrial Waste Exchanges: Fact Sheet, SW-688, 1978, p. 1.

[51] Ibid.

TABLE 10-3
PROJECTED ANNUAL NET INDUSTRIAL SOLID WASTE GENERATION BY MATERIAL[a]
1971, 1980, 1990

Material	Quantity (10^6 Tons) 1971	1980	1990
Ferrous Metals	8.39	8.74	9.41
Aluminum	0.19	0.31	0.50
Copper	0.24	0.20	0.19
Zinc	0.11	0.15	0.21
Lead	0.03	0.04	0.08
Plastics	0.20	0.35	0.69
Rubber	0.19	0.28	0.39
Leather	0.09	0.10	0.13
Textiles	0.17	0.23	0.34
Wood	3.23	3.77	4.42
Paper	0.26	0.33	0.45
Paperboard and Construction	0.46	0.54	0.76
Total	13.56	15.05	17.57

a) Net solid waste refers to the amount of solid waste generated minus the amount of solid waste recovered.

Source: International Research and Technology Corporation, Forecasts of the Quantity and Composition of Solid Waste, IRT - 19300/R-3, June 1979, pp. 33-34.

These categories comprise the major portion of what municipal solid waste disposal facilities handle directly. Other wastes, including industrial wastes, agricultural wastes, sewage sludge, and demolition and construction wastes, may also be disposed of in municipal facilities.[52] These latter wastes are covered in other sections of this chapter.

Three of the available estimates of current and future municipal solid waste generation are summarized in Table 10-4. The first estimate (IR&T) is derived from the projections of the same scenario described for industrial solid wastes (see Section 10.3.2).[53] The second estimate was derived by the EPA Office of Solid Waste and Franklin Associates Ltd. (revised in 1977). It is expected that EPA will soon reevaluate these projections.[54] The third estimate was made by Midwest Research Institute (MRI) for EPA.[55]

Each of these three estimates project moderate growth in net MSW generation between 1975 and 1990. Both IR&T and EPA expect it to reach about 1.3 times the 1975 generation by 1990, while MRI expects it to reach almost 1.5 times the 1975 level by 1990. Considering the uncertainties inherent in projecting waste generation and future recycling, the differences in the estimates are not significant.

Assuming that the trends projected in each of these studies were to continue, annual municipal solid waste generation would reach about 1.6 times the 1975 level (based on the IR&T and EPA projections) or 1.9 times the 1975 level (based on the MRI study).[56]

Each of these studies used different assumptions about the percentage of municipal solid waste that would be recycled. The assumptions used in the IR&T study were equivalent to an assumption that

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[52] International Research and Technology Corporation, Forecasts of the Quantity and Composition of Solid Waste, IRT-19300/R-3, June 1979, p. 15.

[53] Ibid.

[54] U.S. Environmental Protection Agency, Office of Solid Waste, Fourth Report to Congress: Resource Recovery and Waste Reduction, OSW-600, 1977, p. 20.

[55] International Research and Technology Corporation, Forecasts of the Quantity and Composition of Solid Waste, IRT-19300/R-3, June 1979.

[56] These estimates are based on a simple extrapolation to 2000 of the trends in net generation between 1975 and 1990. They do not represent estimates made by either IR&T, EPA, or MRI but are provided for comparative purposes only.

TABLE 10-4
ESTIMATES OF NET MUNICIPAL SOLID WASTE GENERATION[a]

1975 and 1990

(10^6 Tons)

	1975			1990		
	IR&T	EPA	MRI	IR&T	EPA	MRI
Paper	37.5	37.2	42.2	55.4		67.4
Glass	14.2	13.3	14.6	18.6		17.0
Metals	22.0	12.2	13.3	22.8		19.4
Ferrous	(20.1)	(10.8)	(11.7)	(20.2)		(16.4)
Aluminum	(1.1)	(0.9)	(1.2)	(1.5)		(2.3)
Other	(0.9)	(0.4)	(0.4)	(1.2)		(0.7)
Plastics	4.4	4.4	5.7	9.3		13.2
Rubber and Leather	2.5	3.3	3.7	4.7		5.8
Textiles	1.9	2.1	2.1	3.4		3.5
Wood	9.3	4.9	5.1	9.0		7.4
Food Wastes	21.3	22.8	23.0	24.4		27.8
Yard Wastes	24.8	26.0	26.3	32.8		36.5
Misc. Organics	-	1.9	2.1	-		3.3
Total	137.9	128.2	138.2	180.4	167	201.2
Pounds/ Person/day	3.5	3.2	3.5	4.0	3.7	4.5

[a] "Net" solid waste includes all waste generated minus waste removed by recovery methods

[b] Breakdown of 1990 EPA estimate by material not available

Sources: International Research and Technology Corporation, Forecasts of the Quantity and Composition of Solid Waste, IRT 19300/R-3, June 1979, p. 59.
EPA Office of Solid Waste, Fourth Report to Congress: Resource Recovery and Waste Reduction, SW-600, 1977, p. 15.

the percentage of municipal solid waste recycled would increase from about 8 percent in 1971 to about 15 percent in 1990. In contrast, the assumptions used in the EPA study were equivalent to an assumption that the recycling percentage would increase from 6 percent in 1971 and 1975 to 26 percent in 1990. The assumptions used in the MRI study were not available.

More informative than the overall trend in generation is the trend in daily per capita generation (see Table 10-4). Each of the three projections expects daily per capita net municipal solid waste (MSW) generation to increase; the annual MSW disposal requirement is expected to increase even faster than population. Recycling is not expected to offset the growth in MSW generation caused by population growth in any of the three scenarios studied.

The bulk of municipal solid waste is currently disposed of in landfills. Part of this waste is incinerated before landfilling to reduce the volume. In many areas of the country, finding the land needed to dispose of MSW in this fashion is becoming increasingly difficult.

Furthermore, many of the existing landfills used to dispose of MSW will be classified as "open dumps" under the provisions of the Resource Conservation and Recovery Act and therefore must be upgraded or closed. The number of open dumps is unknown, but one estimate is that of 90,000 recognized land disposal sites, only 12,000 could be classified as "sanitary" or "modified sanitary."[57] The remainder would probably be classified as open dumps. These open dumps pose a hazard both to human health and to the environment.

As a result, a great deal of work is being done to develop and implement alternatives to the landfilling of municipal solid wastes. One alternative is to reduce the quantity of wastes generated yearly and hence reduce the landfill requirement. Waste reduction can be achieved through numerous methods. The waste reduction method most familiar to the general public is the beverage container deposit. Six states--Oregon, Vermont, Maine, Michigan, Connecticut, and Iowa--currently have beverage container deposit laws, as well as several counties in other states.[58] The State of Massachusetts may soon also require a deposit on beverage containers.[59] EPA issued guidelines for beverage containers in September 1976, requiring deposits on all beer and soft drinks sold at Federal facilities.[60] The Office of Technology Assessment (OTA) has concluded that beverage container deposits laws would achieve, to varying degrees, reductions in litter, reductions in municipal solid wastes, and savings in energy and materials consumption.[61]

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[57] Research and Education Association, Pollution Control Technology, New York, 1973, p. 488.

[58] Council on Environmental Quality, Environmental Quality - The Ninth Annual Report of the Council on Environmental Quality, U.S. Government Printing Office, Washington, D.C., December, 1978, p. 172.

[59] Ibid, p. 172.

Other waste reduction techniques include lengthening the lifetimes of durable goods (such as appliances), reducing the material used in a product (smaller automobiles, for example), and reducing per capita consumption of goods.[62]

Resource recovery, both materials and energy, is also being pursued extensively as an alternative to the landfilling of municipal solid wastes. There are basically two different approaches to resource recovery; source separation and centralized resource recovery.[63] Source separation is simply "the setting aside of recyclable materials at their point of generation (e.g., the home, or place of business) by the generator." Source separation facilitates the transportation of the materials to secondary users. The techniques of source separation are familiar to most people; these include "curbside collection of newspaper, cans, and glass; commercial recycling of office waste paper, corrugated cardboard, and computer cards; and community dropoff centers."[64]

Source separation has numerous advantages, probably the most important of which are that it produces a high quality product and requires little capital investment as compared with other options. By its very nature, however, it has two serious disadvantages. It has a limited potential for recovering materials from municipal solid wastes and, since it removes the highest quality materials from the waste, the remaining wastes may have a reduced quality both as a materials source and as fuel.[65] Nonetheless, OTA estimates that as much as 27 percent of MSW (by weight) can be recovered using source separation.[66]

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[60] Council on Environmental Quality, Environmental Quality - The Ninth Annual Report of the Council on Environmental Quality, U.S. Government Printing Office, Washington, D.C., December, 1978, p. 172.

[61] Office of Technology Assessment, Congress of the United States, Materials and Energy from Municipal Waste, July 1979, p. 16.

[62] U.S. Environmental Protection Agency, Office of Solid Waste, Fourth Report to Congress; Resource Recovery and Waste Reduction, OSW-600, 1977, p. 21.

[63] Office of Technology Assessment, Congress of the United States, Materials and Energy from Municipal Waste, July 1979, p. 5.

[64] Ibid, p. 69.

[65] Ibid, p. 70.

[66] Ibid, p. 71.

In contrast to source separation, centralized resource recovery systems recover energy and/or recyclable materials from mixed municipal solid wastes in a central facility.[67] Table 10-5 lists the major types of central resource recovery facilities. Of these several are commercially operational; waterwall combustion, small scale modular incinerators with heat recovery, wet and dry solid fuel "refuse-derived fuel" (RDF) processes, compostings, magnetic recovery of ferrous metals, and fiber recovery by wet separation.[68] Numerous centralized resource recovery facilities are now in operation or under construction in the United States (see Table 10-6).

Estimates of the reduction in landfill requirements achievable through centralized resource recovery are uncertain. OTA estimates that a resource recovery plant can reduce the landfill requirement of the MSW processed by 80 to 90 percent by weight.[69] Nationally, the reduction potential would depend on the number of plants. Further, OTA estimates that the total energy savings that were available from centralized resource recovery, in 1975, may have been as high as 2.3 percent of the 1975 United States energy use or about 285 million barrels of oil. Further materials recovery could run as high as 90 to 97 percent (ferrous metals) depending on the technique and the material.[70]

However, there are numerous economic and institutional barriers to the development of centralized resource recovery systems.[71] In most parts of the country, landfilling is more economical than centralized resource recovery.[72] However, in those areas where land is more expensive the economics of resource recovery may favor this option over landfilling. The institutional barriers facing the systems range from information problems to marketing and implementation problems.[73]

While waste reduction and recycling are not likely to eliminate the need for land filling of MSW, active pursuit of these initiatives could definitely reduce the disposal problems facing many urban areas.

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[67] Office of Technology Assessment, Congress of the United States, Materials and Energy from Municipal Waste, July 1979, p. 5.

[68] Ibid, p. 98.

[69] Ibid, p. 125.

[70] Ibid, p. 100.

[71] Ibid, pp. 119-152.

[72] Ibid, p. 7.

[73] Ibid, p. 137.

TABLE 10-5
MAJOR CENTRALIZED RESOURCE RECOVERY SYSTEMS

Energy recovery systems

- Mass combustion of raw MSW[a]
  - Waterwall incineration
  - Small-scale modular incineration with heat recovery

- Refuse derived fuel (RDF)[a]
  - Dry processes
    - Fluff RDF
    - Dustor powered RDF
    - Densified RDF
  - Wet processes

- Pyrolysis systems
  - Low BTU gas
  - Medium BTU gas
  - Liquid fuel

- Biological systems
  - Landfill methane recovery
  - Anaerobic digestion
  - Hydrolysis

Material recovery systems

- Composting[a]
- Ferrous metals[a]
- Aluminum
- Glass
- Fiber
  - Wet separation[a]
  - Dry separation
- Nonferrous metals

[a] Commercially operational technologies.

Source: Office of Technology Assessment, Materials and Energy from Municipal Waste, U.S. Government Printing Office, Washington, D.C., July 1979, p. 95.

TABLE 10-6
RESOURCE RECOVERY FACILITIES IN THE UNITED STATES

Location	Type[a]	Capacity (tons/day)	Products/markets	Startup date
In Operation:				
Altoona, Pa.................	Compost	200	Humus	1963
Ames, Iowa..................	RDF	400	RDF-utility, Fe, Al	1975
Baltimore, Md.(D)...........	Pyrolysis	700	Steam heating & cooling, Fe	1975
Baltimore County, Md.(D)....	RDF	550	RDF, Fe, Al, glass	1976
Blytheville, Ark............	MCU	50	Steam process	1975
Braintree, Mass.............	WWC	240	Steam process	1971
E. Bridgewater, Mass........	RDF	160	RDF-utility	1974
Franklin, Ohio(D)...........	Wet pulp	150	Fiber, Fe, glass, Al	1971
Groveton, N.H...............	MCU	30	Steam process	1975
Milwaukee, Wis..............	RDF	1,000	RDF-utility, paper Fe, Al	1977
Nashville, Tenn.............	WWC	720	Steam heating & cooling	1974
Norfolk, Va.................	WWC	360	Steam (Navy base)	1967
Oceanside, N.Y..............	RWI/WWC	750	Steam	1965/74
Palos Verdes, Calif.........	Methane recovery		Gas-utility & Fe	1975
Saugus, Mass................	WWC	1,200	Steam process	1976
Siloam Springs, Ark.........	MCU	20	Steam process	1975
South Charleston, W.Va.(D)..	Pyrolysis	200	Gas, Fe	1974

(Continued)

TABLE 10-6 (CONCLUDED)

Location	Type[a]	Capacity (tons/day)	Products/Markets	Startup Date
Under construction; startup:				
Akron, Ohio.................	RDF/WWC	1,000	Steam heating and cooling	1978
Bridgeport, Conn............	RDF	1,800	RDF utility, Fe, Al, glass	1978
Chicago, Ill................	RDF	1,000	RDF-utility, Fe	1976
Hempstead, N.Y..............	Wet pulp/WWC	2,000	Electricity, Fe, Al, glass	1978
Lane County, Ore............	RDF/WWC	750	RDF-institution, Fe	1978
Monroe County, N.Y..........	RDF	2,000	RDF-utility, Fe, Al, glass	1978
Mountain View, Calif.(D)....	Methane Recovery		Gas/Utility	1977
New Orleans, La.(D).........	Materials	650	Nonferrous, Fe, glass, paper	1976
Niagara Falls, N.Y..........	RDF/WWC	2,200	Steam industry, Fe	--
North Little Rock, Ark......	MCU	100	Steam process	1977
Portsmouth, Va..............	WWC	160	Steam loop	1976
San Diego, Calif.(D)........	Pyrolysis	200	Liquid Fuel/utility, Fe, Al, glass	1977

[a] RDF = refuse-derived fuel; WWC = waterwall combustion; RWI = refractory wall incinerator with waste-heat boiler; MCU = modular combustion unit; RDF/WWC = waterwall combustion using processed waste; D = Pilot or demonstration facility.

Source: Office of Technology Assessment, Materials and Energy From Municipal Waste, U. S. Government Printing Office, Washington, D.C., July 1979, page 97.

10.4 MINING AND RELATED WASTES

HIGHLIGHTS OF SECTION 10.4

- Annual generation of mining-related wastes is expected to at least double by 2000 and land disposal is expected to remain the major disposal method used. However, an increasing portion of the mining-related wastes may be backfilled because of the requirements of the Surface Mining Control and Reclamation Act.
- Oil shale mining and retorting could generate as much as 1.5 billion tons of solid wastes in 2000, increasing annual mining-related solid waste generation by 25 percent. The disposal of oil shale related wastes may become a problem even though the major portion is expected to be backfilled.

10.4.1 Introduction

Mining-related wastes include overburden or waste rock, tailings or beneficiation wastes, and miscellaneous wastes. Overburden consists of the bedrock, soil, and other unproductive materials that must be removed from a mine along with the ore. Tailings consist of the waste material discarded during ore processing. About 65 percent of all mineral mining solid waste is overburden, 32 percent is tailings, and 3 percent other mine wastes.[74]

These proportions are national averages. Actual proportions are site-specific and also depend heavily on whether the mine is underground or surface type. For example, tailings generally account for about 80 percent of the total solid wastes from underground mines.[75]

Currently the greater portion of mining-related solid wastes are disposed of on land, a practice which results in numerous adverse environmental and health-related effects. Whether such practices will continue in the future in light of the Resource Conservation and Recovery Act,[76] the Surface Mining Control and Reclamation Act,[77] and the Uranium Mill Tailings Radiation Control Act[78] is unknown.

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[74] PEDCo Environmental Inc., Study of Adverse Effects of Solid Waste from All Mining Activities on the Environment, Draft, prepared for EPA Office of Solid Waste, 1979, p. xxxi.
[75] Ibid.
[76] Mining wastes have temporarily been classified as special wastes under RCRA. Federal Register, December 18, 1978, p.58902.
[77] Surface Mining Control and Reclamation Act of 1977, PL 95-87.
[78] Uranium Mill Tailings Radiation Control Act of 1978, PL 95-604.

However, these acts should result in a lessening of the adverse environmental and human health effects of land disposal of mine wastes.

The following discussion of the generation and disposal of mining wastes deals first with ores and mineral fuels currently mined in the United States. The mining and retorting of oil shale and resulting waste generation are then discussed.

10.4.2 Mining Wastes

Introduction

The mining of metallic and nonmetallic ores and mineral fuels is the largest single source of solid waste in the United States. The following discussion centers around the trends in mining waste generation, and current and future disposal practices for those ores and mineral fuels currently being mined.

Trends

Current estimates of the annual generation of mining solid wastes range from 2.3 billion tons to 3.3 billions tons.[79] Further, an estimated 30 billion tons of solid wastes from mining had accumulated at mining sites by 1975. This estimate is based on annual solid waste production statistics rather than directly on disposal data, but it does serve to illustrate the magnitude of the accumulation.[80]

Using estimates of annual ore production and ratio of ore to solid waste, PEDCo Environmental Inc. has projected annual mining solid waste generation through the year 2000.[81] The annual ore production projections made by PEDCo are summarized in Table 10-7, and the waste generation projections are shown in Table 10-8. PEDCo's estimate of 1975 generation is 2.3 billion tons.

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[79] PEDCo Environmental Inc., Study of Adverse Effects of Solid Waste from All Mining Activities on the Environment, Draft, prepared for EPA Office of Solid Waste, 1979, p. xxxi. Also, U.S. Environmental Protection Agency, Office of Water and Waste Management, EPA Activities Under the Resource Conservation and Recovery Act, Fiscal Year 1978, SW-755, Washington, D.C., March 1979, pp. 1-2.

[80] PEDCo Environmental Inc., Study of Adverse Effects of Solid Waste from All Mining Activities on the Environment, Draft, prepared for EPA Office of Solid Waste, 1979, p. xxxii.

[81] Ibid.

TABLE 10-7
PROJECTED ANNUAL ORE PRODUCTION BY SELECTED INDUSTRIES

Industry	Crude Ore to Marketable Product Ratio	Crude Ore Production (10^6 Tons) 1975	1985	2000
Copper	193.5 : 1	270	480	730
Iron Ore	2.8 : 1	240	260	320
Uranium	630.9 : 1	7	23	38
Phosphate Rock	3.8 : 1	190	300	320
Coal[a]	NA	650	1000	1660
Other	NA	1890	3100	5260
Total	NA	3250	5170	8340

NA - Not Applicable

a) Total for all mineral fuels - anthracite, lignite, and bituminous coal.

Source: PEDCo Environment Inc., Study of Adverse Effects of Solid Waste from All Mining Activities on the Environment, Draft, prepared for U.S. Environmental Protection Agency Office of Solid Waste, 1979.

TABLE 10-8
PROJECTED ANNUAL GENERATION OF MINING SOLID WASTES BY SELECTED INDUSTRIES

Industry	Waste to Ore Ratio	1975		1985		2000	
		Quantity (10^6 Tons)	Percent of Total	Percent of 1975 Value	Percent of Total	Percent of 1975 Value	Percent of Total
Copper	3.56	960	41	190	43	270	45
Iron Ore	1.73	410	18	110	11	130	9
Uranium	23.65	160	7	330	13	550	15
Phosphate Rock	1.9	350	15	160	14	170	10
Coal[a]	0.17	110	5	160	4	260	5
Other[b]	NA	330	14	190	15	270	15
Total	NA	2,300	100	180	100	250	100

[a] Total for tailings from bituminous and lignite coal only.

[b] Includes only metal and nonmetal ores.

Source: PEDCo Environmental Inc., Study of Adverse Effects of S d Wa s from All Mining Activities on the Environment, Draft, prepared for the ironm ital Protection Agency Office of Solid Waste, 1979.

This estimate unquestionably is low, since it is known that the coal industry as a whole generates more mining solid wastes than all other mining industries combined,[82] and Table 10-8 is based on only partial data for the coal industry.[83] Aside from coal, the four major industry sources were copper, iron, uranium, and phosphate rock mines, which together generated almost three-fourths of the listed 1975 total.

The uranium and phosphate rock industries are of major importance not only because of their large volumes of waste but also because mining waste from these industries has been declared a special waste under RCRA.[84]

Annual generation of mining solid wastes is expected to increase significantly by 2000, as shown in Table 10-8. Total generation is expected to exceed 4 billion tons by 1985 and reach almost 6 billion tons by 2000. The most rapid growth is expected by 1985. Since coal is expected to be a major source of energy in the future, and the coverage of the coal industry is incomplete in the PEDCo report, these projections of mining waste generation are definitely low.

Using a different definition of mining wastes than that used in the PEDCo report, estimates of the trend in the annual requirement for coal mining waste disposal are available from SEAS. These estimates indicate that annual coal mining waste generation is expected to rise to about 2.8 times the 1975 level in the High Growth Scenario and 2.1 times the 1975 level in the Low Growth Scenario.

The copper industry, according to the Table 10-8 projections, is expected to remain the largest single source of mining solid waste, other than coal mining, increasing generation to 2.7 times the 1975 level by 2000. The iron ore industry, on the other hand, is expected to exhibit a significantly slower increase in generation of mining wastes than the other industries, reaching only 1.3 times its 1975 generation in 2000.

The uranium industry, as illustrated in Table 10-8, is expected to show the greatest relative increase in annual mining waste generation, increasing by a factor of about 5 between 1975 and 2000. This increase is lower than those projected in the SEAS High Growth and Low Growth Scenarios, which have factors of 7.5 and 6.0, respectively.

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[82] PEDCo Environmental Inc., Study of Adverse Effects of Solid Waste from All Mining Activities on the Environment, Draft, prepared for EPA Office of Solid Waste, 1979, p. xxviii.

[83] This estimate covers tailings only. Data for overburden and development waste rock are not available for the coal mining industry.

[84] "Hazardous Waste: Proposed Guidelines and Regulations and Proposal on Identification and Listing," Federal Register, December 18, 1978, Part IV, pp. 58946-58959.

Since the PEDCo study assumes that waste to ore ratios of all industries remain constant at 1975 levels, these increases directly reflect increases in ore production. The validity of this assumption is uncertain, since as ore demand increases, a larger portion of marginal ores may have to be mined in some industries. This could serve to increase the amount of waste generated per unit quantity of ore produced. Whether the resulting increase in solid waste generation would be significant is not known.

Current and Future Disposal Techniques

The disposal options for overburden and tailings are rather restricted. Table 10-9 summarizes the methods currently employed in the disposal of mining solid wastes.

Ninety percent of the overburden and waste rock is disposed of in piles on or near the mine site. The remaining 10 percent is either backfilled into the mine or used for on-site construction or holding pond covers. Several factors, particularly transportation difficulties, restrict off-site utilization. At present, the amount of off-site use of overburden and waste rock is "minuscule."[85]

Economic and physical factors currently favor piling of overburden and waste rock rather than backfilling in many mines, particularly in eastern surface coal mines. However, the implementation of the Surface Mining Control and Reclamation Act[86] may cause an increase in the use of backfilling as a disposal method, at least in surface coal mining.

The overwhelming proportion (99+ percent) of tailings is disposed of in holding ponds. Many of the ponds have clay liners to prevent leaching as the water in the tailings evaporates. When the pond is filled, mine overburden may be used to cover it.[87]

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[85] PEDCo Environmental Inc., Study of Adverse Effects of Solid Waste from All Mining Activities on the Environment, Draft, prepared for EPA Office of Solid Waste, 1979, p. xliii.

[86] Surface Mining Control and Reclamation Act of 1977, PL 95-87.

[87] PEDCo Environmental Inc., Study of Adverse Effects of Solid Waste from All Mining Activities on the Environment, Draft, prepared for EPA Office of Solid Waste, 1979, p. xliii.

TABLE 10-9
DISPOSAL METHODS FOR MINING WASTES

Type of Solid Waste	Disposal Method
Overburden and waste rock	Stockpiles adjacent to surface and underground mines and on the outside slopes of open pit mines (90 percent)
	Backfilling of previously excavated areas adjacent to the active overburden removal at surface mines. Backfilling of underground mines with waste rock (0-10 percent)
	Utilization as construction material (0-10 percent)
Tailings from the mills of both underground and surface mines.	Tailings pond (99+ percent)
	Backfilling underground mines either by sluicing or truck hauling.
	Utilization as construction material.
Miscellaneous wastes	Combinination with overburden, waste rock, and/or tailings.
	Separate disposal in a sanitary landfill on or off site
	Lake/marine disposal

Source: PEDCo Environmental Inc., Study of Adverse Effects of Solid Wastes from All Mining Activities on the Environment, Draft, prepared for U.S. Environmental Protection Agency, Office of Solid Waste, 1979, pp. xxxix - xLi.

The disposal of uranium mill tailings is controlled under the Uranium Mill Tailings Radiation Control Act.[88] This Act requires that uranium mill tailings be disposed of in a manner safe for human health and the environment.

Alternative disposal methods of tailings are also limited. Hydraulic backfilling of tailings has been used in some mines but there are many disadvantages to this method. Tailings may also be used in highway construction, both on and off site, antiskid material, and concrete and asphalt paving aggregates. However, many of the factors restricting use of overburden also restrict the use of tailings.

10.4.3 Oil Shale Wastes

Introduction

Two forms of solid wastes appear as major by-products of oil shale production: mine overburden and spent oil shale. Surface overburden at an oil shale mine ranges between 100 and 800 feet thick.[89] It has been estimated that a typical 66,000 ton per day (raw shale) surface mine would produce 71,000 tons per day of overburden requiring disposal.[90] However, the actual amount of overburden generated is highly site-specific. Currently the intention is to backfill all overburden.

Spent shale is the main solid waste byproduct of surface oil shale retorting and upgrading. According to current plans, 60 percent of the spent oil shale would be returned to the mine site.[91] The remainder would probably be deposited in surface holding ponds. These disposal plans may be subject to change, however, as spent oil shale may be declared a hazardous waste on the basis of the potential of spent oil shale wastes to leach numerous dissolved solids.

In contrast to surface retorting, true in situ oil shale processes extract the oil from the shale underground. In doing so, they produce no spent oil shale as a waste requiring disposal.

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[88] Uranium Mill Tailings Radiation Control Act of 1978, PL 95-604.

[89] The MITRE Corporation, Environmental Data for Energy Technology Policy Analysis, Volume III: Fossil Fuels, Draft MTR-7992, May 1979, p. III-3.

[90] U.S. Environmental Protection Agency, Energy From the West, Energy Resource Development Systems Report, Volume III: Oil Shale, EPA-60018-79-0606, March 1979, p. 96.

[91] The MITRE Corporation, Environmental Data for Energy Technology Policy Analysis, Volume III: Fossil Fuels, Draft MTR-7992, May 1979, p. III-3.

The problem of safely disposing of oil shale wastes from surface operations may enhance the market position of in situ techniques. Therefore, the trends reported here, which assume limited in situ retorting, may significantly overestimate oil shale waste generation.

Trends

In 1975, oil shale was not being processed commercially in the United States. Oil shale production in the Mountain Region (Federal Region VIII) is projected to reach 0.9 quadrillion Btu (or quads) annually in 1985, 2.1 quads in 1990, and 5.4 quads in 2000, under the SEAS High Growth Scenario assumptions. In the SEAS Low Growth Scenario, oil shale development is projected to lag by about five to 10 years, with production growing to 0.1 quad in 1985, 0.9 quad in 1990, and 2.2 quads in 2000. Within High Growth levels of production, an increasing portion is assumed to come from in situ oil shale techniques: 11 percent in 1985, 15 percent in 1990, and 20 percent in 2000. Under Low Growth assumptions, in situ techniques are not implemented until 2000, when it is assumed that 10 percent of oil shale would be processed using such techniques.

The oil shale production levels projected in both scenarios would result in significant production of solid waste by this industry (Figure 10-2). Wastes would become substantial by 1985 under High Growth and by 1990 under Low Growth.

Using the oil shale production levels projected in the High Growth Scenario and assuming that a 66,000 ton per day (raw shale) surface mine would generate 71,000 tons per day of overburden, annual overburden generation is expected to reach about 150 million tons in 1985 and almost 800 million tons in 2000. Similarly, using Low Growth oil shale production projections, annual overburden generation is expected to be over 165 million tons in 1990 and over 365 million tons in 2000.

Annual production of spent shale is projected to reach 132 million tons in 1985 under High Growth assumptions and 148 million tons in 1990 under Low Growth assumptions. By 2000 the figure would reach over 700 million tons in High Growth and about half that amount in the Low Growth Scenario.

Disposal of Oil Shale Wastes

As mentioned, it is anticipated that about 60 percent of the spent shale will be disposed of in the mine itself, that is, backfilled. It is also expected that, after an initial delay, ranging from 1 to 30 years depending on the type of surface mine, most of the overburden will be backfilled. The remainder of the wastes will be disposed of in either landfills or holding ponds.

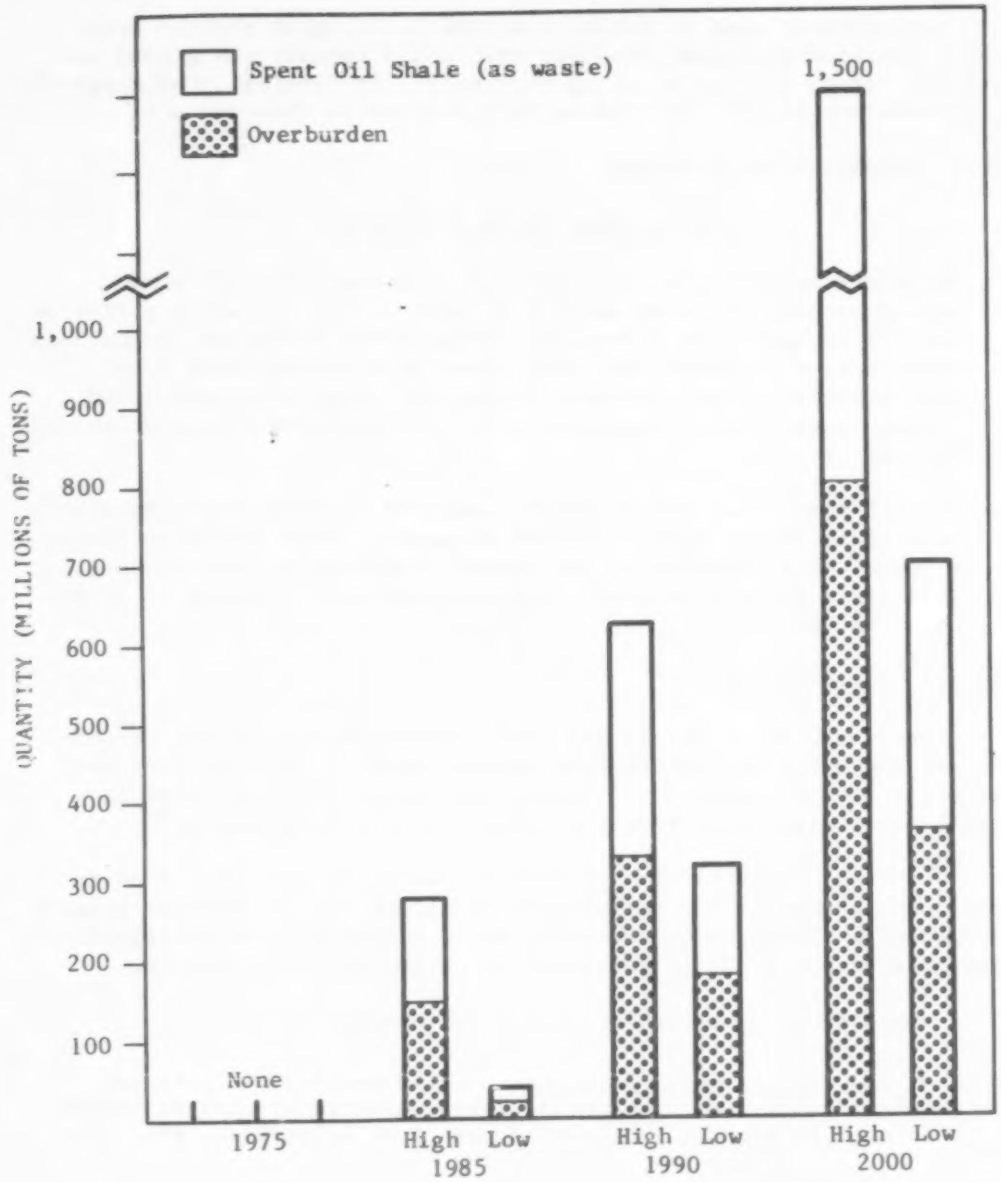

FIGURE 10-2
TRENDS IN GENERATION OF
OIL SHALE WASTES
1975, 1985, 1990, 2000

Precautions must be taken in disposing of spent shale. Spent shale contains numerous compounds that could contaminate ground and surface waters through leaching or runoff. In contrast, the disposal of overburden is not expected to be a problem in this respect.

10.5 SECONDARY SOLID WASTES

HIGHLIGHTS OF SECTION 10.5

- Secondary solid wastes are expected to become more and more important over the next several decades as air and water pollution control becomes more effective. These solid wastes are pollutants removed from wastestreams, many times in a concentrated form. Safe disposal is particularly urgent for those secondary solid wastes identified as hazardous under the Resource Conservation and Recovery Act.

- As with many other solid wastes, the primary method used to dispose of secondary wastes is land disposal. Even though there are a number of alternatives (the number depending on what the waste is), it is anticipated that land disposal will continue to be the major method used.

10.5.1 Introduction

Secondary solid wastes are those wastes created by the removal of air and water pollutants from wastestreams. The treatment and safe disposal of these solid wastes represents the final link in a chain of efforts to improve the quality of the environment.[92]

For this analysis, the pollutant removed by the control equipment that generates the solid waste is called the "associated primary pollutant." Examples of secondary solid wastes include municipal sewage sludge and sludge generated by sulfur oxides scrubbers.

Three types of secondary wastes are considered:

- Noncombustible solid waste. A wide variety of waste byproducts, including particulates captured by control equipment in the wastestreams of coal combustion facilities and cement factories. Since bottom ash is disposed of along with fly ash in most combustion facilities, trends in its generation are discussed with captured fly ash even though bottom ash is not a secondary solid waste.

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[92] There is a question as to whether a safe disposal of secondary solid wastes is feasible. If not, the question becomes whether the pollutant associated with the waste is less of a danger in the wastestream. The intermedial relationships between pollutants that arise due to regulations are now being examined by EPA, but the data necessary to make comparisons are sorely lacking. As a result, questions of this nature cannot be addressed in this chapter.

- Industrial sludge. Industrial wastewater treatment sludges and the sludges generated by the removal of sulfur oxides and particulates from stack gases by wet scrubbers.[93]
- Municipal sewage sludge. The sludge generated by the removal of suspended solids and organic matter in municipal sewage treatment facilities.

The generation of each type of secondary solid waste raises the problem of adequate disposal. Present methods generally involve some form of treatment (i.e., dewatering and reduction) and eventual removal to a holding pond or landfill. Electric utilities and some other industries usually dispose of solid waste on or near the plant site, eliminating the need to transport the waste--which is, in general, an expensive step.

However, the leachate from disposal sites of many of these wastes may contain toxic and otherwise dangerous compounds and elements, such as arsenic, cadmium, and lead. As a result, the ground and surface waters of the surrounding areas may become contaminated. Further, certain of these wastes may promote the growth of infectious bacteria and disease-carrying insects.

Because of these factors, some of these wastes may be declared special or hazardous under the provisions of the Resource Conservation and Recovery Act. The impacts of such a declaration depend on the waste category and the strictness of the regulations that may be promulgated in the future. At a minimum, such a declaration will restrict the methods used to dispose of many of these wastes.

Because of the preliminary status of the RCRA regulations, they have not yet been integrated into SEAS. However, EPA regulations on air and water pollutant releases are incorporated into the system. As discussed in Chapters 4 and 6, the model's projections are predicated on full compliance with these regulations by industry by certain deadlines. Since the generation of secondary solid wastes depends entirely on the quantity of the associated primary pollutant removed from the wastestream, the validity of the projections of future secondary solid waste generation is very sensitive to the full compliance factor. Nonetheless, since full compliance with these regulations would result in the maximum amount of secondary solid wastes being generated, these projections are a reasonable basis for analysis.

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[93] Actual moisture content of sludge varies considerably. Flue gas desulfurization sludges, for example, range between 35 and 75 percent moisture. Municipal sewage sludge may be as high as 99 percent moisture. The generation of both industrial and municipal sludges is reported in dry tons.

Several general scenario assumptions affect secondary solid waste generation. The assumption having the greatest effect is that the United States will make increasing use of its coal supplies. Significant increases in the use of coal as a primary fuel source are projected in both High and Low Growth Scenarios. More and more of this coal is expected to come from western coal mines, almost one-half by 2000 as compared with 14 percent in 1975. It is further assumed that by 2000, half of all coal mined annually will be cleaned. Thus the country is projected to depend more and more on cleaner coal.

The amount of a secondary solid waste generated depends on the amount of the associated primary pollutant removed from the wastestream. SEAS uses simple multipliers to convert the estimates of the captured primary pollutant into estimates of net solid wastes, taking into account such factors as moisture content and chemical relationships.

Since these factors vary from waste to waste, a different multiplier is used for each waste. For example, the multiplier assumed for scrubber sludge is 2.55, which means that 2.55 dry tons of scrubber sludge are generated for each ton of sulfur oxide removed.[94] Removal multipliers of 1.0 for dry particulates and total suspended solids (TSS), 0.3 for BOD, and 2.55 for wet particulates are used in SEAS. Thus the validity of the trends in the secondary solid waste projections depends on both the accuracy of these multipliers and the quality of the associated primary pollutant data. (see Chapters 4 and 6 for information about sources and quality of these air and water pollutant data.)

The industry coverage for secondary solid wastes associated with air pollutant controls is good. Because of the complexity of industrial wastewater treatment technologies, the coverage of secondary solid wastes from such sources is poor. Estimates for municipal sewage sludge are based on one of the best current sources on the future treatment of municipal sewage,[95] so the quality of these projections is considered reasonably high.

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[94] The use of this multiplier is equivalent to assuming that all SO_x scrubbers are nonregenerable.

For each type of secondary solid waste studied, both national and regional generation trends are discussed. Major industrial sources are identified and causes for change in the generation by those sources are analyzed. The impacts and implications of these generation trends on environmental quality are assessed in Section 10.7.

10.5.2 Noncombustible Solid Wastes

HIGHLIGHTS OF SECTION 10.5.2

- Annual generation of noncombustible solid waste is expected to increase by 2000 to over three times the 1975 level under conditions of high economic growth and 2.6 times this level with low economic growth. Under the Resource Conservation and Recovery Act, much of this waste is classified as "special waste" (e.g., ash from coal combustion and dust from cement production).
- Most of the noncombustible solid wastes are generated in the Middle Atlantic, Southeast, Great Lakes, and South Central Regions.
- Current disposal generally involves landfill or ponding, a practice that is expected to continue. However, much of this type of waste could be recycled, depending on demand for products such as lightweight fly ash concrete aggregates.

Introduction

Noncombustible solid waste (NCSW) is comprised mainly of captured particulates and bottom ash from combustion processes and captured dust from numerous production activities. At present, NCSW is disposed of in various ways, but mostly by some form of landfill or ponding. These procedures may change, since at least two major types of NCSW have tentatively been designated by EPA as special wastes: ash from coal-fired utilities and primary cement kiln dust.[96] The trends in the generation and disposal of these and other noncombustible solid wastes are discussed in this section.

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[95] U.S. Environmental Protection Agency, Cost Estimates for Construction of Publicly Owned Wastewater Treatment Facilities, Needs Survey 1976, EPA 44019-76-010 (MCD-48A), 1977.

[96] "Hazardous Waste: Proposed Guidelines and Regulations and Proposal on Identification and Listing," Federal Register, Part IV, December 18, 1978, p. 59015.

Trends in Generation of Noncombustible Solid Wastes

The projected national trends in generation of NCSW are summarized in Table 10-10, which also identifies the major contributing industries. In 1975, ash removal in coal-fired electric utilities accounted for over half of the 82 million tons of NCSW produced. Dust control in the primary cement industry generated another 19 percent, while only two other industries, asphalt and petroleum refining and storage (8 percent each), contributed more than 3 percent to the national total NCSW generation in that year.[97]

Generation of NCSW is projected to almost double from 1975 to 1985 and to triple by 2000 in the High Growth Scenario. That is, annual production of NCSW would increase from 82 million tons in 1975 to 158 million tons in 1985 and 248 million tons in 2000. Significant but less rapid increase is projected in the Low Growth Scenario (generation of 140 million tons in 1985 and 210 million tons in 2000).

The major share of noncombustible solid waste is expected to result from the removal of particulates and bottom ash by coal-fired electric utilities (see Figure 10-3). Because of the assumed national trend toward greater use of coal and because of more stringent requirements for removal of particulates,[98] annual production of NCSW by coal-fired electric utilities is projected to increase to 260 percent of the 1975 level, or to approximately 110 million tons, by 2000 in the High Growth Scenario (NCSW would increase to 220 percent of the 1975 level by 2000 in the Low Growth Scenario). Without these regulations, the major portion of this 110 million tons would be released to the atmosphere as particulates.

Controlling kiln dust in the primary cement industry, as assumed in both scenarios, would produce about two and one-half times the 1975 amount of NCSW. Due to a slight improvement in the control of airborne particulates assumed for this industry, this growth in NCSW slightly exceeds the projected growth in cement production. Under state regulations (SIPs) this industry was required to remove about 97 percent of the particulates from gaseous wastestreams. A more stringent requirement--99.7 percent removal--is imposed by the New

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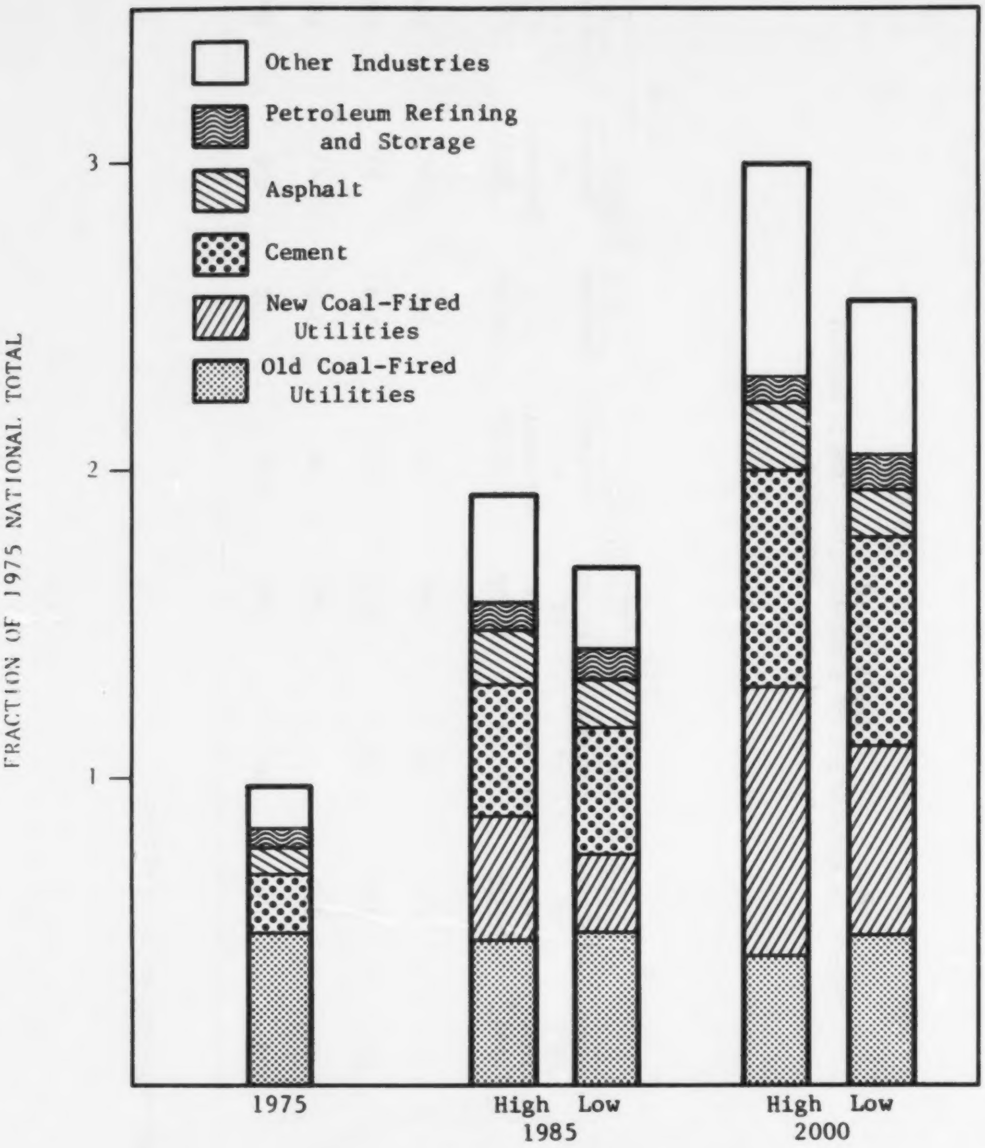
[97] Due to an oversight in the documentation of SEAS, the composition of the NCSW from petroleum refining and storage as interpreted in SEAS is unknown. It probably represents captured particulates.

[98] New Source Performance Standards (NSPS) and Best Available Control Technology (BACT) regulations.

TABLE 10-10
TRENDS IN GENERATION OF NONCOMBUSTIBLE SOLID WASTES BY MAJOR CONTRIBUTING INDUSTRIES

	1975[a]		1985				2000			
			High Growth		Low Growth		High Growth		Low Growth	
Industry	Quantity (10^6 Tons)	Percent of National Total[a]	Percent of 1975 Value	Percent of National Total[a]	Percent of 1975 Value	Percent of National Total[a]	Percent of 1975 Value	Percent of National Total[a]	Percent of 1975 Value	Percent of National Total[a]
Coal Fired Utilities	41.7	51	180	46	150	45	260	44	220	43
Cement	15.9	19	220	22	220	25	360	23	350	26
Other	24.2	30	210	32	170	30	340	33	260	30
Total	81.8	100	190	100	170	100	300	100	260	100

[a] Rounding may create inconsistencies in addition.



NOTE: 1975 national total = 81.8 million tons.

FIGURE 10-3
TRENDS IN GENERATION OF
NONCOMBUSTIBLE SOLID WASTE
BY MAJOR INDUSTRIES
1975, 1985, 2000

Source Performance Standards.[99] As a result, this industry is expected to account for about one-fourth of the national NCSW generation by 2000.

Several other activities are projected to contribute to the higher NCSW production. These activities include particulate control in asphalt and steel production, industrial combustion of coal, and the production of synthetic fuels from coal. Although individually these activities would not be major contributors to the national totals of NCSW, they could be responsible for portions of regional increases.

The national trends in generation of NCSW are generally repeated on the regional level. The NCSW increases in each region, along with regional distribution of the national total of NCSW, are shown in Table 10-11. In 1975, four regions--the Middle Atlantic, Southeast, Great Lakes, and South Central (Federal Regions III, IV, V, and VI)--together were estimated to have accounted for 80 percent of the national NCSW generation.

In three of these four regions (Federal Regions III, IV, and V), most of the NCSW is generated by four industries: coal-fired utilities and the cement, asphalt, and steel industries. The coal-fired utilities and cement industries are projected to account for at least 70 percent of the NCSW generation in each of these three regions throughout the 1975 to 2000 period (Figure 10-4). In Federal Region VI, although petroleum refining and storage and the cement industry were the major contributors of NCSW as of 1975, coal combustion is expected to become dominant by 2000.

The aggregate NCSW generation within these four regions is expected to increase somewhat less rapidly than the national total. This is due primarily to a projection of less rapid growth in coal use in Federal Regions III, IV, and V than in the nation as a whole. Thus, the proportion of the annual national NCSW from these four regions is expected to decline from 80 percent shown in 1975 to about 70 percent for the period 1985 through 2000.

However, in the South Central Region (Federal Region VI) the trend is different, and much more substantial increases in NCSW generation are anticipated by 2000. In that region, which accounted for 13 percent of the national NCSW generation in 1975, NCSW generation is projected to reach more than five times 1975 levels by 2000 under High Growth assumptions, and four times 1975 levels under Low Growth.

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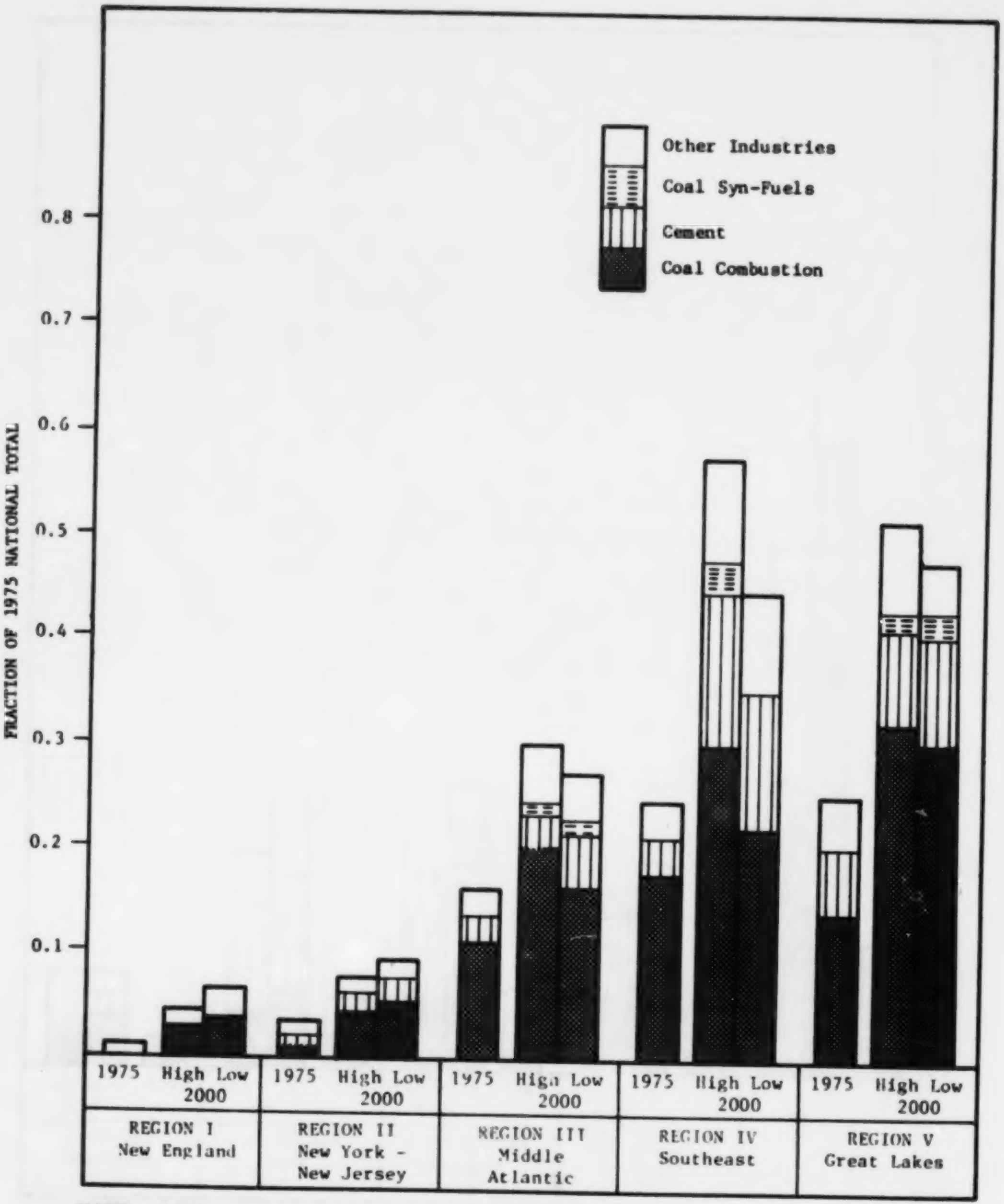
[99] Adapted for use in SEAS from Title 40, Chapter 1, Subpart F, Section 60.60-60.64 of the Code of Federal Regulations.

TABLE 10-11
TRENDS IN REGIONAL GENERATION OF NONCOMBUSTIBLE SOLID WASTE

Region	1975^a		1985				2000			
			High Growth		Low Growth		High Growth		Low Growth	
	Quantity (10^6 Tons)	Percent of National Total	Percent of 1975 Value	Percent of National Total [a]	Percent of 1975 Value	Percent of National Total [a]	Percent of 1975 Value	Percent of National Total[a]	Percent of 1975 Value	Percent of National Total[a]
I. New England	0.7	1	380	2	420	2	630	2	730	2
II. New York-New Jersey	2.1	3	190	3	230	3	270	3	320	3
III. Middle Atlantic	13.3	16	140	12	130	12	180	10	160	10
IV. Southeast	19.9	24	140	17	120	17	240	19	180	18
V. Great Lakes	20.3	25	180	22	170	24	210	17	200	20
VI. South Central	10.5	13	290	19	220	17	540	23	420	21
VII. Central	4.8	6	220	7	190	7	340	7	300	7
VIII. Mountain	4.0	5	300	8	270	8	550	9	430	8
IX. West	4.9	6	250	8	230	8	420	8	350	8
X. Northwest	1.2	2	390	3	260	2	780	4	540	3
Total	81.8	100	190	100	170	100	300	100	260	100

[a] Rounding may create inconsistencies in addition.



NOTE: 1975 national total = 81.8 million tons.

FIGURE 10-4
TRENDS IN REGIONAL GENERATION OF
NONCOMBUSTIBLE SOLID WASTE
BY MAJOR INDUSTRIES
1975 AND 2000

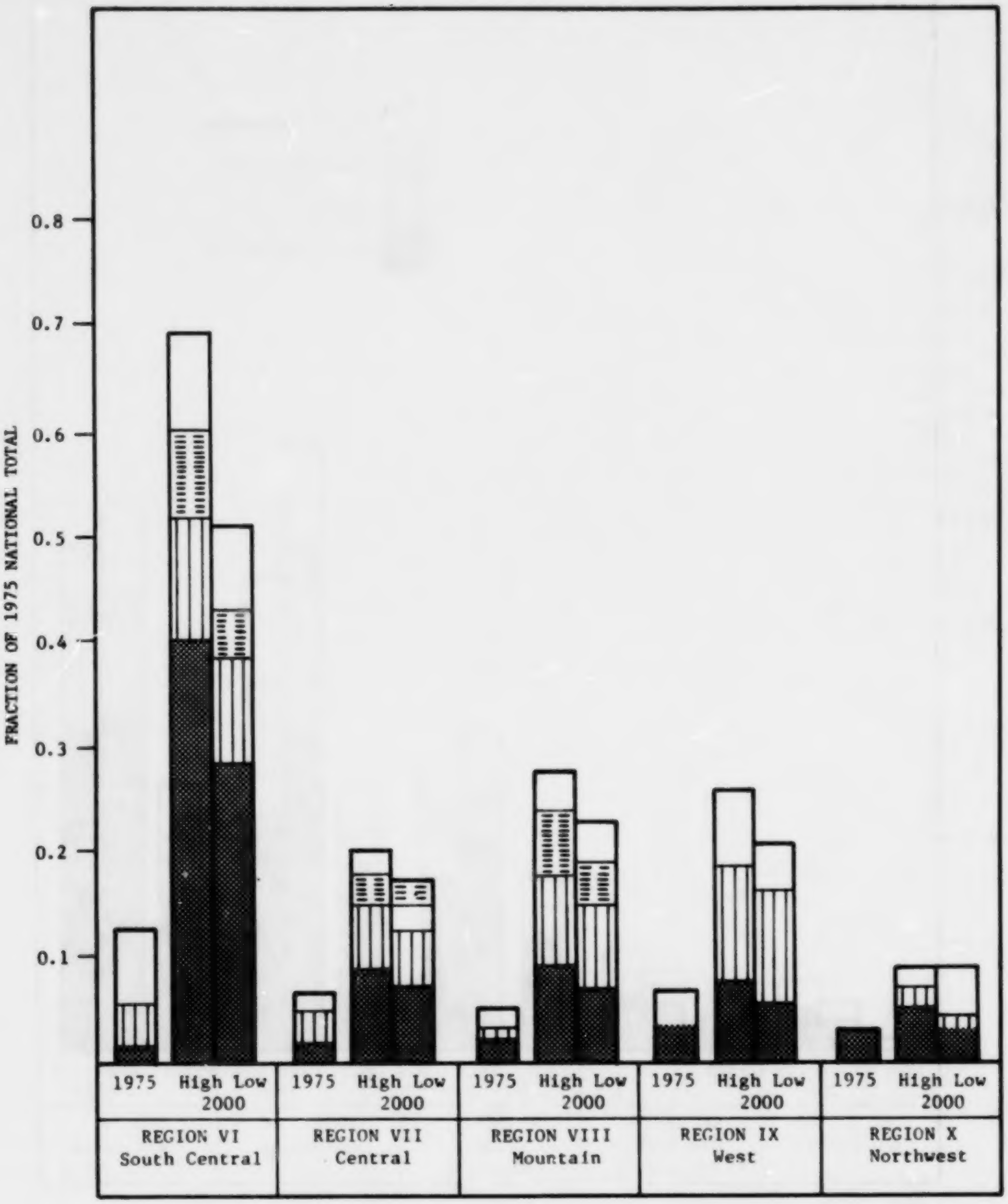


FIGURE 10-4
CONTINUED

Trends for the major industries generating NCSW within Federal Region VI are shown in Table 10-12. Overall electric power generation in this region is expected to more than double in both scenarios by 2000. Coal-fired power plants, which accounted for about 10 percent of the electricity produced in Federal Region VI in 1975, exhibit marked growth in power output in both scenarios. By 2000, coal-fired utilities are projected to provide about 55 percent of the electricity consumed in this region under High Growth assumptions (about 40 percent in Low Growth). Further, coal is expected to provide about 40 percent of the industrial combustion demand by 2000 in the High Growth Scenario (30 percent under Low Growth) as it is increasingly substituted for natural gas. This represents a significant increase over 1975 industrial use (which was about 2 percent of the total).

This projected high increase in the use of coal in electric power generation and in industrial combustion facilities is the reason for the projection noted earlier, that the level of NCSW generation in Federal Region VI will grow faster than in Federal Regions III, IV, and V. Noncombustible solid waste levels from coal combustion in Federal Region VI are projected to rise from 1.3 million tons in 1975 to 16 million tons in 1985 and almost 33 million tons by 2000 in the High Growth Scenario. Under Low Growth assumptions, NCSW generation from coal combustion increases less rapidly, reaching 10 million tons in 1985 and about 23 million tons by 2000.

The primary cement industry is also expected to provide a significant portion of the anticipated increases in NCSW generation in Region VI, accounting for 25 percent of the total in both scenarios throughout the 1975 to 2000 period.

Disposal of Noncombustible Solid Wastes

This discussion will be limited to the disposal of NCSW generated by the two major sources identified in the preceding section: coal-fired power plants and the primary cement industry. Most of the techniques these industries use apply to any industry.

The primary methods coal-fired power plants use to dispose of NCSW are ponding and landfill. According to a recent study, 50 percent of the fly ash and 30 percent of the bottom ash were disposed of in landfills in 1976, and 35 percent of the fly ash and 45 percent of the bottom ash were disposed of in ponds.[100] The remainder of the ash is disposed of in some other manner or is re-used. The

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[100] Radian Corporation, Study of Nonhazardous Wastes from Coal-Fired Utilities, Draft, DCN-200-18/-41-08, prepared for EPA Industrial Environmental Research Laboratory, RTP, December 1978, pp. 108-112.

TABLE 10-12
TRENDS IN GENERATION OF NONCOMBUSTIBLE SOLID WASTE BY MAJOR CONTRIBUTING INDUSTRIES
REGION VI

	1975		1985				2000			
			High Growth		Low Growth		High Growth		Low Growth	
Industry	Quantity (10^6 Tons)	Percent of Regional Total[a]	Percent of 1975 Value	Percent of Regional Total[a]	Percent of 1975 Value	Percent of Regional Total[a]	Percent of 1975 Value	Percent of Regional Total[a]	Percent of 1975 Value	Percent of Regional Total[a]
Petroleum Refining Storage	4.3	41	80	12	80	16	90	7	80	8
Cement	2.6	25	220	19	220	25	420	20	370	25
Coal Fired Electric Utilities	1.2	12	740	30	450	24	1,370	30	920	26
Industrial Coal Combustion	0.1	1	6,640	23	4,100	19	14,580	28	10,580	26
Other	2.2	21	240	17	180	17	420	16	340	17
Total	10.5	100	290	100	220	100	540	100	420	100

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[a] Rounding may create inconsistencies in addition.

difference in the disposal practices for fly ash and bottom ash is apparently due to the predominance of wet sluiced collection methods in removing bottom ash from utility boilers.[101]

The cement industry relies heavily on on-site landfills for NCSW disposal, according to the Portland Cement Association, although a portion of the waste is used for various other purposes.[102]

The future trends in both of these industries are expected to be toward landfilling rather than ponding.[103]

To illustrate the potential land requirement for land for disposal: If all of the utility ash expected to be generated in the year 2000 under High Growth assumptions were compacted to a density of 1 ton per cubic yard and placed in a landfill 30 feet deep, the total surface area requirement just for coal-fired utilities' NCSW in that year alone would be approximately 3.5 square miles, or about 2,300 acres.

Many ways for utilizing ash exist as alternatives to landfill and ponding disposal. The use of utility ash in the United States in 1975 is summarized in Table 10-13. According to Argonne National Laboratory, the United States utilized between 14 and 17 percent of the ash produced in the three years previous to 1975. In contrast, European countries used a much greater portion of the fly ash produced--79 percent in the Federal Republic of Germany, 54 percent in the United Kingdom, and 44 percent in Belgium and Poland.[104]

Some of the potential uses for coal ash are listed in Table 10-14. Several organizations, such as the National Ash Association, the Bureau of Mines, the Department of Transportation, EPA, and various state and local governmental agencies, as well as commercial ash utilization firms, have been active in recent years in promoting more use of ash. These efforts have met with some success. In future years, greater quantities of ash probably will be used, but not

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[101] Radian Corporation, Study of Nonhazardous Wastes from Coal-Fired Utilities, Draft, DCN-200-18/-41-08, December 1978, p. 111.

[102] Personal communication, Cleve Schneeberger and Rob Crolius, Portland Cement Association, Washington, D.C., June 13, 1979.

[103] Radian Corporation, Study of Nonhazardous Wastes from Coal-Fired Utilities, Draft, DCN-200-18/-41-08, December 1978, pp. 15-16. Also, personal communication, Cleve Schneeberger and Rob Crolius, Portland Cement Association, Washington, D.C., June 13, 1979.

[104] Argonne National Laboratory, Environmental Control Implications of Generating Electric Power From Coal: Technology Status Report, Volume II, ANL/ECT-1, December 1976, p. 180.

TABLE 10-13
COMMERCIAL UTILIZATION OF ASH IN THE UNITED STATES[a]
1975
(Thousands of Tons)

Use	Fly Ash	Bottom Ash	Boiler Slag
Type 1-P Cement	225	70	36
Partial Substitute for Cement	945	-	-
Lightweight Aggregate	90	35	-
Stabilization & Roads	450	525	72
Filler in Asphalt Mix	135	-	-
Ice Control	-	280	54
Blast Grit & Roof Granules	-	420	864
Miscellaneous	180	350	414
Ash Removal at no Cost to Utility[b]	1,080	875	270
Ash Utilized[b] from Disposal Sites	1,395	945	90
1975 Total Utilized	4,500	3,500	1,800

[a] Compiled by the National Ash Association and Edison Electric Institute.

[b] Specific end use not known.

Source: Argonne National Laboratory, Environmental Control Implications of Generating Electric Power From Coal: Technology Status Report, Volume II, ANL/ECT-1, December 1976, p. 181.

TABLE 10-14
POTENTIAL USES FOR COAL ASH

Blended Cements

Pavements (LFA and LCFA mixtures)

Roadfill

Sand Blasting Grit

Brick

Component of Grout

Filler Material

Extinguisher for Spoil Pile Fires

Lightweight Concrete

Asphalt Pavements

Anti-skid Agent

Load-bearing Fill

Soil Amendment

Mineral Wood Production

Source of Chemicals

Source: Argonne National Laboratory, Environmental Control Implications of Generating Electric Power From Coal: Technology Status Report, Volume II, ANL/ECT-1, December 1976, pp. 180-184.

necessarily a greater portion of the ash produced, since the generation of coal ash is projected to grow much more rapidly than the potential demand for ash by industrial users.

There are numerous beneficial uses of cement kiln dust as well. Because of its high lime content, this form of NCSW has been used as a soil additive and fertilizer. Other possibilities include use as a cattle feed additive, in soil stabilization, as filler material in roofing, shingles, and asphalt, and in certain process for paper making.[105] However, utilization of kiln dust in these ways is not expected to offset the projected increases in dust production.

The declaration of either of these forms of NCSW as hazardous or special waste under the Resource Conservation and Recovery Act would have a definite impact on the respective industries. An extensive analysis on the composition of kiln dust and on the economic impact of RCRA on the cement industry is planned by both government agencies and private concerns. Numerous studies are also being undertaken on the potential impacts of RCRA on the coal-fired utilities industry.

10.5.3 Industrial Sludge

HIGHLIGHTS OF SECTION 10.5.3

- Estimates of trends in generation of industrial sludge are of limited usefulness because of insufficient data on industrial wastewater treatment, a major contributor. With this exception noted, annual generation by 2000 is expected to increase tenfold. Most of this waste is scrubber sludge, which is classified as "special waste" under the Resource Conservation and Recovery Act.

- While marked increase in sludge generation is expected in all regions, four regions--Middle Atlantic, Southeast, Great Lakes, and South Central--account for almost three-fourths of the total.

- Most industrial sludges are disposed of in ponds or ultimately in landfills. However, recycling and process changes offer promise of reducing the amount of industrial sludge, especially hazardous waste, that requires disposal.

Introduction

Industrial sludge is generated, as a secondary solid waste, by the removal of sulfur oxides and particulates in gaseous wastestreams and by the treatment of industrial wastewater. The SEAS estimates of industrial sludge generation are fairly inclusive except for industrial wastewater treatment, where SEAS estimates sludges only for the steel industry. A preliminary SEAS-based estimate indicates that the national industrial sludge estimate may be as much as a factor of 7 too low in 1975 and a factor of 3 too low in 2000. Hence, the overall SEAS estimate of annual industrial sludge generation is definitely low.

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[105] Personal Communication, Cleve Schneeberger and Rob Crolius, Portland Cement Association, Washington, D.C., June 13, 1979.

A preliminary estimate of the total quantity of industrial sludge generated annually was based on the amount of captured total suspended solids (TSS) estimated in SEAS and assumed a multiplier of 1.0. This estimate indicates that the projected quantity of industrial sludge generated, if all industrial wastewater treatment sludges were included, would be at least three times that presently projected in SEAS. As a result, these projections are strongly weighted toward scrubber sludge as the major type of industrial sludge--a projection that does not reflect actual conditions.

As in the case of noncombustible solid wastes, most of the industrial sludge produced is disposed of in either landfills or ponds. Coal-fired utilities usually dispose of sludge and ash together. Use of present procedures is not expected to continue in the future, since many industrial sludges have been tentatively declared hazardous or special by EPA.[106]

The trends in the levels of industrial sludge projected in both scenarios are discussed in this section. Industrial wastewater treatment sludges not explicitly covered in SEAS are not analyzed.

Trends in Industrial Sludge Generation[107]

Four manufacturing industries generated the major portion--98 percent--of the estimated 8.3 million tons of industrial sludge produced in 1975 according to SEAS (see Table 10-15). This sludge was generated by wet scrubbers used to control particulates in the asphalt, lime, and pulp and paper industries and by industrial wastewater treatment in the steel industry. These control measures are mandated under provisions of the Clean Air Act and the Federal Water Pollution Control Act. No other industry generated more than 1 percent of the 1975 total.

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[106] Federal Register, Volume 40, pp. 58957-58959, 58992, December 18, 1979.

[107] The reader is again cautioned that the trends presented in this section must be viewed in the light of the lack of coverage for industrial wastewater treatment sludges.

TABLE 10-15
TRENDS IN GENERATION OF INDUSTRIAL SLUDGE BY MAJOR CONTRIBUTING INDUSTRIES[a]

	1975[b]		1985				2000			
			High Growth		Low Growth		High Growth		Low Growth	
Industry	Quantity (10^6 Tons)	Percent of National Total	Percent of 1975 Value	Percent of National Total[b]	Percent of 1975 Value	Percent of National Total[a]	Percent of 1975 Value	Percent of National Total[b]	Percent of 1975 Value	Percent of National Total[b]
Asphalt	4.6	55	190	18	170	23	220	11	200	12
Steel	1.8	21	200	7	180	10	220	4	200	5
Lime	1.2	14	160	4	150	5	230	3	200	3
Pulp and Paper	0.7	8	170	2	150	3	280	2	220	2
Coal Combustion	<0.1	1	48,000	69	30,000	60	$>10^5$	81	87,000	79
Old Coal Electric Utilities	<0.1	1	2,590	4	2,810	6	2,290	2	2,530	2
New Coal Electric Utilities	0	0	-	52	-	44	240[c]	62	330[c]	65
Industrial Coal Combustion	0	0	-	13	-	10	250[c]	17	260[c]	11
Petroleum Refining Storage	<0.1	1	110	<1	100	<1	130	<1	120	<1
Total	8.3	100	580	100	410	100	1,140	100	920	100

[a] Since SEAS does not presently adequately cover industrial wastewater treatment sludges, this table constitutes a partial listing.

[b] Rounding may create inconsistencies in addition.

[c] Percent of 1985 value.

Annual industrial sludge generation is expected to increase fivefold by 1985 and tenfold (to 95 million tons) by 2000 in the High Growth Scenario (see Figure 10-5). In the Low Growth Scenario, the increase is somewhat less rapid, tripling by 1985 and increasing eightfold, to 76 million tons, by 2000.

This marked increase in sludge generation is due mainly to the imposition of stringent requirements for the control of sulfur oxides and particulate emissions on coal-burning power plants and industrial combustion facilities to bring about improvements in air quality (for more information on standards see Appendix A).[108] These coal combustion sources, according to SEAS estimates, generated less than 100 thousand tons of industrial sludge in 1975, but they are projected to generate about 33 million tons in 1985 and 76 million tons in 2000 under High Growth assumptions. In the Low Growth Scenario, the projections are somewhat lower, about 20 million tons in 1985 and 60 million tons in 2000. In both scenarios, these sources alone are projected to produce more than twice as much sludge annually by 1985 as did all sources in 1975.[109]

The removal of an increasingly greater portion of sulfur oxides from gaseous wastestreams in coal-fired utilities results in sludge generation increases greater than the projected increases in the use of coal by these utilities. The use of coal by coal-fired utilities is projected to rise from about 9 quads[110] in 1975 to about 17 quads by 2000 under High Growth assumptions and about 13 quads by 2000 under Low Growth assumptions.

The annual generation of industrial sludge by the asphalt, steel, and lime industries by the year 2000 is expected to rise by 125 percent in the High Growth Scenario (100 percent under Low Growth). These projected increases result primarily from higher output, but some increase can be attributed to greater air and water pollution control.

Regional growth and distribution in industrial sludge generation for 1975, 1985, and 2000 are shown in Table 10-16. Marked growth in the generation level is projected for all regions in both scenarios (see Figure 10-6).

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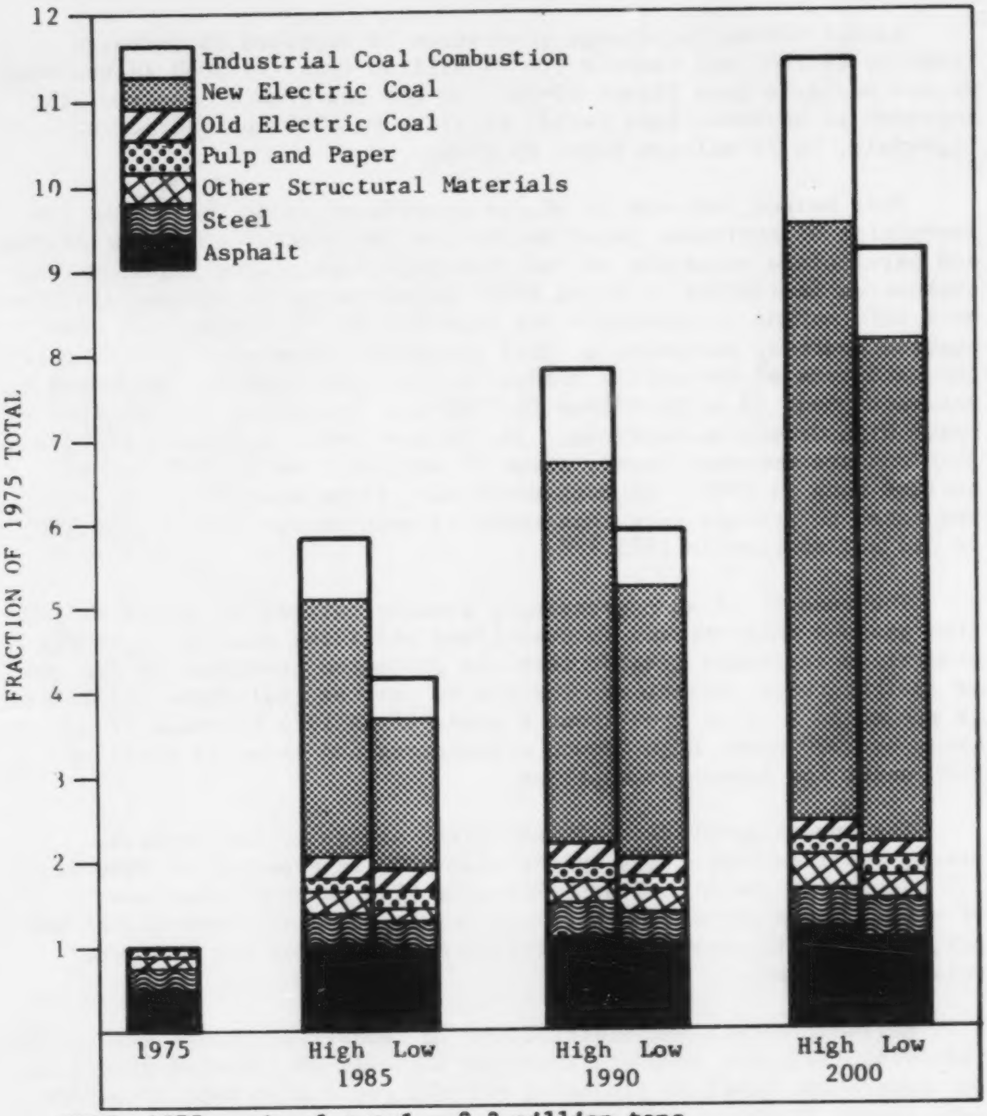
[108] The reader is again cautioned that the trends presented in this section must be viewed in the light of the lack of coverage for industrial wastewater treatment sludges.

[109] These projections are based on regulations proposed before the most recent NSPS revision. Under the most recent revision, it is anticipated that scrubber sludge generation would be slightly lower than under the preceding version.

[110] Quad = 1 quadrillion Btu. One quad is the energy equivalent of more than 170 million barrels of crude oil.



NOTE: 1975 national total = 8.3 million tons.

FIGURE 10-5
TRENDS IN GENERATION OF
INDUSTRIAL SLUDGE BY MAJOR INDUSTRIES
1975, 1985, 1990, 2000

TABLE 10-16
TRENDS IN REGIONAL GENERATION OF INDUSTRIAL SLUDGE[a]

Region	1975		1985				2000			
			High Growth		Low Growth		High Growth		Low Growth	
	10^6 Tons	Percent of National Total[b]	Percent of 1975 Value	Percent of National Total[b]	Percent of 1975 Value	Percent of National Total[b]	Percent of 1975 Value	Percent of National Total[b]	Percent of 1975 Value	Percent of National Total[b]
I. New England	0.3	4	380	2	470	4	1,020	3	1,440	6
II. New York-New Jersey	0.5	6	370	4	590	8	780	4	1,060	6
III. Middle Atlantic	1.0	12	570	12	370	11	1,120	12	790	8
IV. Southeast	1.5	18	830	26	490	22	1,750	28	1,240	24
V. Great Lakes	2.4	29	510	25	360	25	860	21	710	22
VI. South Central	1.0	12	860	17	560	15	1,800	19	1,360	18
VII. Central	0.2	3	1,080	5	670	5	2,100	5	1,680	5
VIII. Mountain	0.4	5	390	3	310	4	630	3	550	3
IX. West	0.7	9	220	3	210	4	420	3	320	3
X. Northwest	0.3	4	280	2	230	2	670	2	540	2
Total	8.3	100	580	100	410	100	1,140	100	920	100

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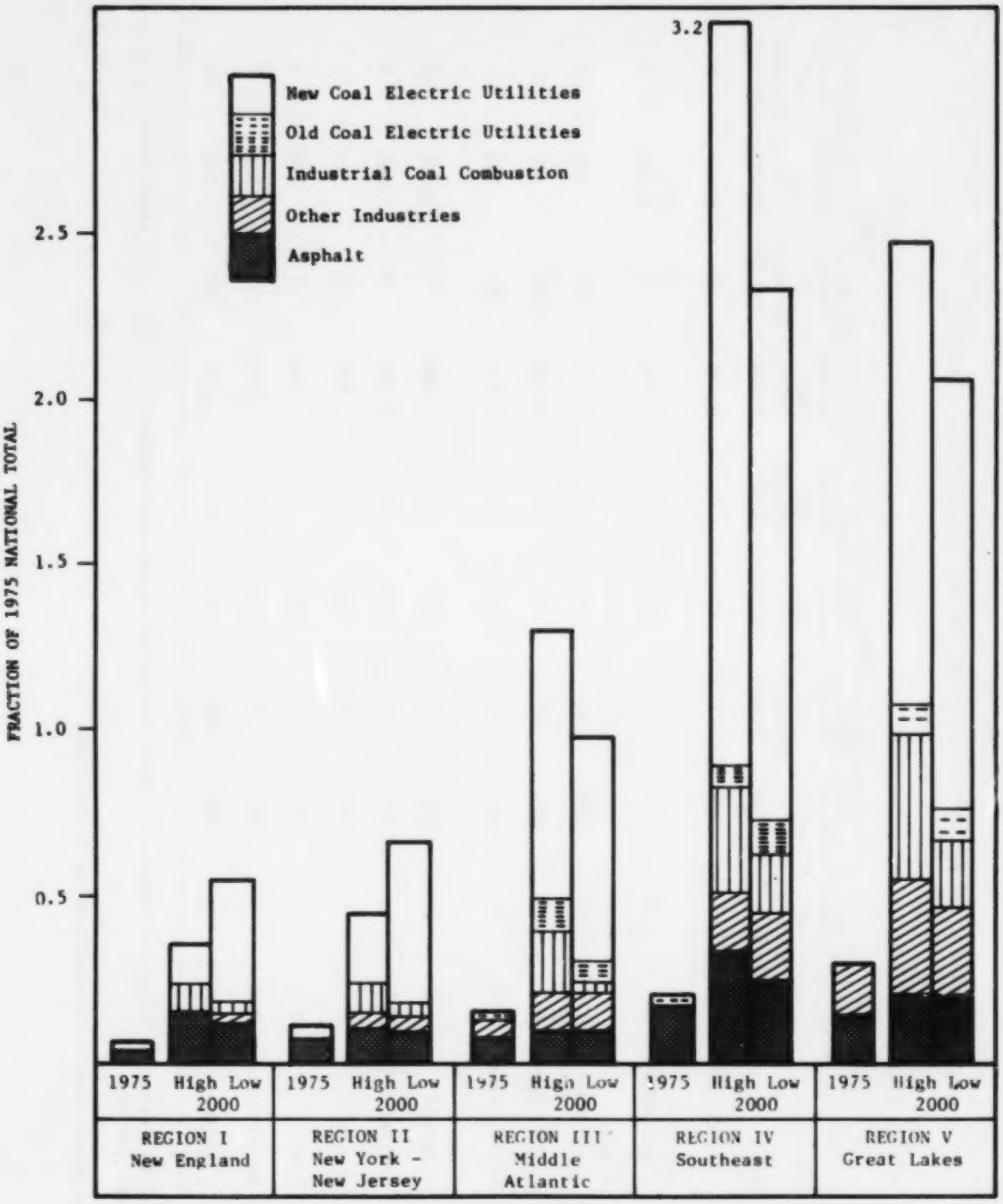
[a] Since SEAS does not presently adequately cover industrial wastewater treatment sludges this table constitutes a partial listing.

[b] Rounding may create inconsistencies in addition.



NOTE: 1975 national total = 8.3 million tons.

FIGURE 10-6
TRENDS IN REGIONAL GENERATION OF INDUSTRIAL SLUDGE BY MAJOR INDUSTRIES 1975 AND 2000

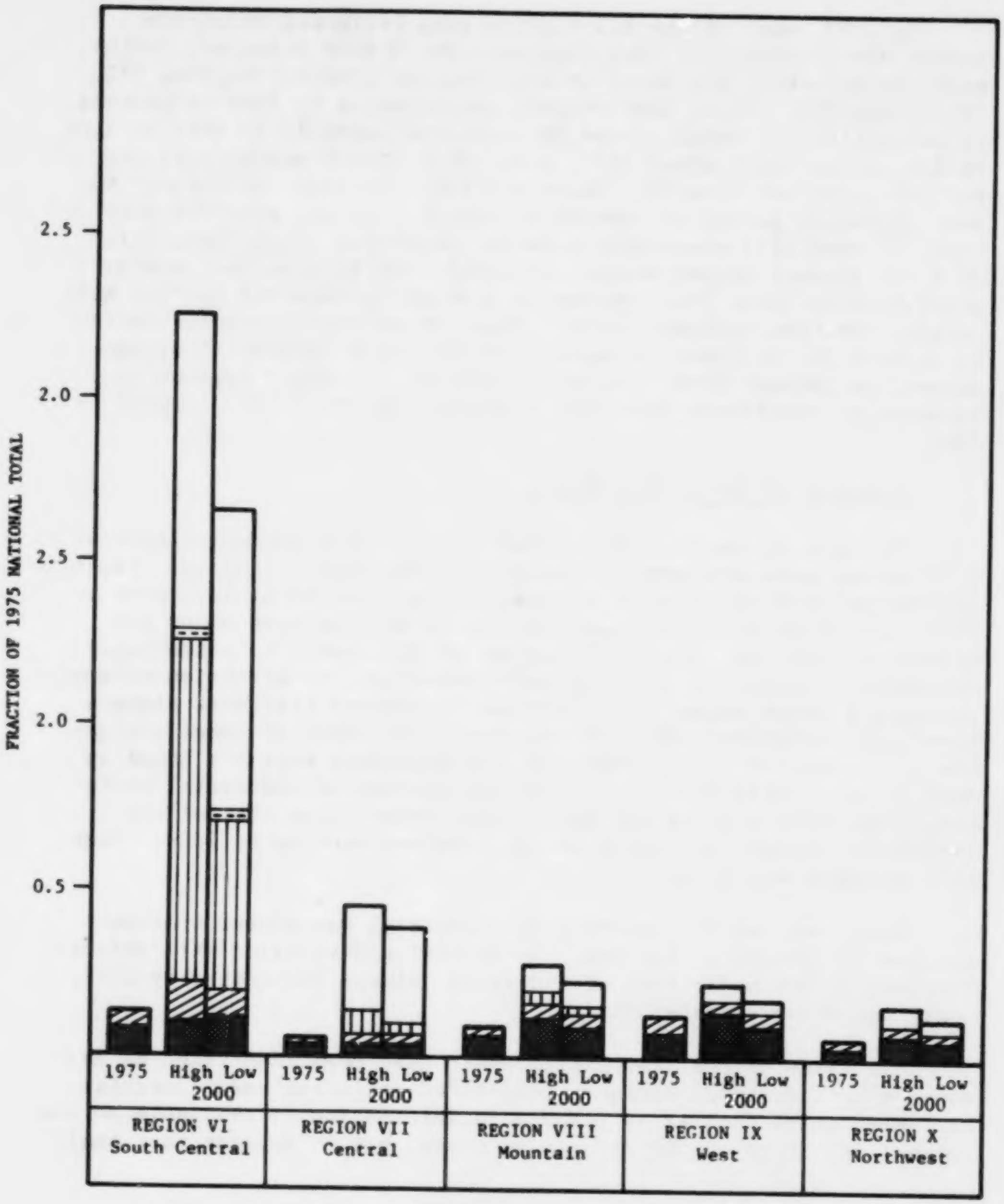


FIGURE 10-6
CONTINUED

In 1975, most of the 8.3 million tons estimated industrial sludge was generated in four regions: the Middle Atlantic, Southeast, Great Lakes, and South Central Regions (Federal Regions III, IV, V, and VI). These four regions are expected by 2000 to consume 71 percent of the total amount of coal used annually in this country in facilities built after 1975, under High Growth assumptions (64 percent under Low Growth). Since new installations are subject to more stringent pollution control standards than are pre-1976 facilities,[111] they will contribute more to industrial sludge generation on a per product output basis. Primarily for this reason, sludge generation in these four regions as a whole is expected to rise more rapidly than the national total. Thus, these regions would continue to account for at least 70 percent of projected industrial sludge generation through 2000. In both scenarios, no other regions are expected to contribute more than 6 percent of the national total by 2000.

Disposal of Industrial Sludge

The safe disposal of industrial sludges from pollution control will become more and more difficult over the next 25 years. Annual generation of these sludges is expected to reach 95 million tons by 2000 under High Growth assumptions and 76 million tons under Low Growth assumptions. Fully 80 percent of this waste is potentially hazardous "special waste" from coal-combustion air pollution control. Further, a large number of industrial wastewater treatment sludges have been tentatively declared hazardous.[112] Most of these sludges are not accounted for in SEAS, but a preliminary estimate based on SEAS material indicates that annual generation of industrial wastewater treatment sludges may be at least three times that of the industrial sludges discussed in the previous section by 2000. Even this estimate may be low.

Since data on the quantity of industrial wastewater treatment sludges are generally lacking, the following discussion will address disposal of the major type of industrial sludge identified by SEAS, coal-combustion scrubber sludge.

Two types of coal combustion users have been identified as major sources of industrial sludge: coal-fired utilities and industrial coal-combustion facilities. Not much information is available on the current practices of the industrial users, but it appears that small facilities dispose of their sludge in municipal refuse facilities while larger firms use some form of on-site landfill or ponding.[113]

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[111] New Source Performance Standards (NSPS) and Best Available Control Technology (BACT) regulations, in contrast to State Implementation Plans (SIPs).

[112] Federal Register, Volume 40, pp. 58946, 59028, December 18, 1979.

Several studies of the sludge disposal methods of the electric utility industry have been made.[114] There is some disagreement as to the number of plants using ponds as a disposal method, but it appears that at least 60 percent of the plants generating sludge in 1977 used this method to dispose of the sludge.[115] The remaining 40 percent used some form of landfill. One report examined mentioned that the current trend is toward landfilling rather than ponding as a disposal method.[116]

Land disposal of scrubber sludge requires a large amount of land. The disposal of the 75 million tons of scrubber sludge projected to be generated annually by 2000 under High Growth assumptions could require about 2.5 square miles or 1,580 acres of ponding 30 feet deep.[117] The amount of land that would be required if a landfill were used would be similar.

Fewer alternative methods exist for disposal of scrubber sludge than for coal ash. The major alternative to land disposal is disposal in coal mines--in deep mines as a subsidence inhibitor, and in surface mines for land reclamation purposes. Cost and technical barriers hinder the use of these options.[118]

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[113] Personal communication, Jan Auerbach, EPA Office of Solid Waste, July 1979.

[114] Radian Corporation, Study of Nonhazardous Wastes from Coal-Fired Utilities, Draft, DCN-200-18/-41-08, December 1978; Argonne National Laboratory, Environmental Control Implications of Generating Electric Power from Coal: Technology Status Report, Volume II, ANL/ECT-1, December 1976; Fred C. Hart Associates, Implications of the Designation of Energy Related Waste as Special Waste, March 1979.

[115] Radian Corporation, Study of Nonhazardous Wastes from Coal-Fired Utilities, Draft, DCN-200-18/-41-08, December 1978, p. 15. Also, Fred C. Hart Associates, Implications of the Designation of Energy Related Waste as Special Waste, March 1979, p. 7.

[116] Radian Corporation, Study of Nonhazardous Wastes from Coal-Fired Utiliies, Draft, DCN-200-18/-41-08, December 1978, p. 15.

[117] Assuming a coefficient of about 2,170 pounds per cubic yard of ponding area, 30 feet deep. Based on calculations made in Radian Corporation, Study of Nonhazardous Wastes from Coal-Fired Utilities, Draft, DCN-200-18/-41-08, December 1978, pp. 126-129.

[118] Ibid, pp. 20-21.

The potential alternative uses of scrubber sludge parallel those of ash. These include: recovery of chemicals, manufacture of buildings materials, structural fill, paving materials, and soil stabilization. The most promising uses are in the production of gypsum wallboard and the utilization of gypsum in Portland cement manufacture.

The recycling of scrubber sludge through the use of regenerable scrubbers would undoubtedly decrease the amount of sludge generated annually.[119] A number of different regenerable scrubber systems are being developed and tested at this time. If a suitably large market can be found for the sulfur or sulfuric acid produced by these systems, some of the systems may be economically competitive with lime/limestone scrubbers when sludge disposal costs are included.[120] As disposal costs rise, therefore, regenerable scrubbers become more attractive economically, adding incentive to the search for solutions of the remaining technical problems.

The treatment of scrubber sludges by dewatering and stabilization increases the utility of the sludge. The removal of water by centrifugation, vacuum filtration, or mechanical thickening, and the addition of chemical stabilizers, such as fly ash and lime, improve the physical and chemical characteristics of the sludge. At the least, the treatment makes the land disposal of the sludges safer.

10.5.4 Municipal Sewage Sludge

HIGHLIGHTS OF SECTION 10.5.4

- Annual generation of municipal sewage sludge is expected to about double between 1975 and 2000. Most of the increase is due to improvements in municipal wastewater treatment prompted by the requirements of the Federal Water Pollution Control Act; a little more than one-fourth of the increase is due to population growth. Little change is expected in the regional distribution.
- Landfilling and ocean dumping are the major sewage sludge disposal methods now in use. Ocean dumping will generally be prohibited after 1981. Several alternatives to landfilling, including land farming, composting, conversion to fuels, and direct combustion, are being investigated.

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[119] It should be noted that regenerable scrubbers currently are being used in some locations.

[120] Radian Corporation, Study of Nonhazardous Wastes from Coal-Fired Utilities, Draft, DCN-200-18/-41-08, December 1978, pp. 176-190.

Introduction

A large number of options are currently being investigated to aid in disposing of municipal sewage sludge, which is the secondary solid waste produced by municipal wastewater treatment. These options include landfill and ponding, land application as a nutrient source, and use of sludge as a fuel source.

Currently municipal sewage sludge which may reach navigable waters is exempt from Subitle C of the Resource Conservation and Recovery Act, which deals with hazardous waste, because it is regulated under the Clean Water Act.[121] However, municipal sewage sludge is covered by RCRA's Subtitle D which will have an impact on how sewage sludge is disposed of, particularly the extent to which it can be used as a soil nutrient source.

Two factors determine the generation of municipal sewage sludge: population growth and the level of municipal wastewater treatment. The level of treatment projected in a region depends on the portion of the regional population served by municipal sewage systems, and the degree of treatment projected to be achieved in both existing and planned municipal waste treatment plants. Improvements in the degree of municipal waste treatment are expected as a result of the implementation of the effluent standards promulgated pursuant to the Federal Water Pollution Control Act (FWPCA, PL 92-500). The following analysis will discuss both the national and the regional trends in municipal sewage sludge and identify the extent to which each of the two factors determine the trends.

Trends in Municipal Sewage Sludge Generation

National trends in the annual generation of municipal sewage sludge are illustrated in Figure 10-7. An increase of 55 percent over the 1975 level of about 3 million tons is expected by 1985 under High Growth assumptions, with an additional increase of only 15 percent of the 1975 total between 1985 and 2000. Increases anticipated in the Low Growth Scenario are slightly smaller because projected population growth is lower.

As evidenced in Figure 10-7, most of the projected growth in annual municipal sewage sludge generation is the result of the compliance with Clean Water Act provisions that is assumed in the

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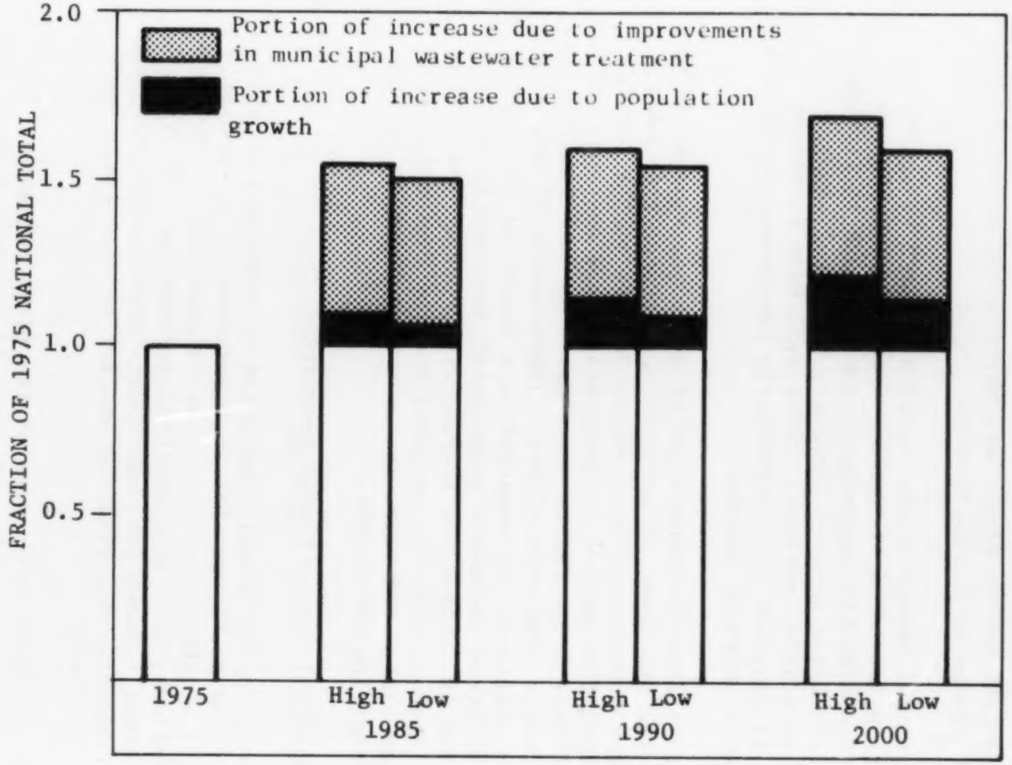
[121] For the purposes of this chapter, the term "Clean Water Act" will refer to the Federal Water Pollution Control Act as amended by PL 92-500 of 1972 and the Clean Water Act of 1977 (PL 95-217), unless otherwise stated. See Chapter 6.



NOTE: 1975 national total = 3.1 million tons.

FIGURE 10-7
TRENDS IN GENERATION OF MUNICIPAL SLUDGE
1975, 1985, 1990, 2000

model. This factor would account for about 85 percent of the increases projected to occur between 1975 and 1985 and about 70 percent of those between 1975 to 2000 in both scenarios. After 1985, the degree of municipal waste treatment is assumed to remain constant, with new treatment plants being built only as the growth in population demands. Thus, population growth is the sole cause of the increase projected to occur between 1985 and 2000.

Since the rates of population growth and the average overall efficiency of municipal waste treatment vary among the federal regions, generation of municipal sewage sludge is projected to increase at different rates from region to region. However, there is only a small variance in the expected increases between the regions. As a result, since many of the projected large relative increases are associated with fairly small absolute increases, only minor changes are expected over time in the regional distribution of total national generation of sewage sludge (see Table 10-17).

The anticipated implementation of the Clean Water Act standards is expected to account for at least 65 percent of the near-term increase (by 1985) in municipal sewage sludge within each region in both scenarios. For the long term (by 2000), this factor is expected to account for 45 percent of the increase in the High Growth Scenario and 55 percent of the long-term growth in the Low Growth Scenario (see Table 10-18).

Disposal of Sewage Sludge

Three methods of sewage sludge disposal are in general use in the United States. According to one estimate, about 50 percent of the annual generation of sewage sludge is disposed of on land, 35 percent is incinerated, and 15 percent is dumped in the ocean.[122]

Land disposal of sewage sludge presents a number of potential hazards to human health and the environment if performed indiscriminantly. Possibly the most serious potential hazard is the result of the presence of pathogens in sewage sludge. The potential exists for intestinal parasites, viruses, and bacteria to enter both the environment and the human food chain if sewage sludge is not disposed of properly. In order to minimize the impact of land disposal of sewage sludge on human health and the environment, EPA has promulgated regulations jointly under the Resource Conservation and Recovery Act (PL

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[122] Council on Environmental Quality, Environmental Quality--The Ninth Annual Report of the Council on Environmental Quality, Washington, D.C., December 1978, p. 161.

TABLE 10-17
TRENDS IN REGIONAL GENERATION OF MUNICIPAL SEWAGE SLUDGE

	1975[a]		1985				2000			
			High Growth		Low Growth		High Growth		Low Growth	
Region	10^6 Tons	Percent of National Total	Percent of 1975 Value	Percent of National Total [a]	Percent of 1975 Value	Percent of National Total [a]	Percent of 1975 Value	Percent of National Total [a]	Percent of 1975 Value	Percent of National Total[a]
I. New England	0.1	3	180	3	180	3	200	3	190	3
II. New York-New Jersey	0.2	7	200	10	200	10	220	9	210	9
III. Middle Atlantic	0.3	9	150	10	150	9	160	9	160	9
IV. Southeast	0.5	15	150	16	150	15	180	16	160	16
V. Great Lakes	0.6	21	140	20	140	19	150	18	140	19
VI. South Central	0.4	14	140	13	140	13	170	14	150	13
VII. Central	0.2	7	130	6	130	6	140	6	130	6
VIII. Mountain	0.1	4	140	3	130	3	160	3	140	3
IX. West	0.5	16	170	18	170	18	190	19	180	19
X. Northwest	0.1	3	150	3	150	3	180	3	160	3
Total	3.1	100	150	100	150	100	170	100	160	100

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[a] Rounding may create inconsistencies in addition.

TABLE 10-18
PERCENT OF INCREASE IN MUNICIPAL SEWAGE SLUDGE DUE TO POPULATION GROWTH AND INCREASED LEVEL OF WASTE TREATMENT

	1975-1985				1975-2000			
	High Growth		Low Growth		High Growth		Low Growth	
Region	Population Growth	Level of Waste-treatment	Population Growth	Level of Waste-treatment	Population Growth	Level of Waste-treatment	Population Growth	Level of Waste-treatment
I. New England	11	89	8	92	20	80	15	85
II. New York-New Jersey	3	97	1	99	7	93	5	95
III. Middle Atlantic	14	86	8	92	25	75	18	91
IV. Southeast	32	68	29	71	46	54	40	60
V. Great Lakes	15	85	9	91	27	73	20	80
VI. South Central	33	67	31	69	52	48	42	58
VII. Central	13	87	4	96	26	74	20	80
VIII. Mountain	40	60	31	69	56	44	44	56
IX. West	20	80	18	82	33	67	26	74
X. Northwest	26	74	20	80	41	59	33	67
Total	18	82	14	86	31	69	15	75

94-580) and the Clean Water Act (PL 95-217).[123] These regulations require that sewage sludge, if landfilled, must be disposed of in a sanitary landfill and that measures be taken to prevent the contamination of ground and surface water. These regulations also include provisions concerning the application of sewage sludge to land. Sewage sludge can be applied to land as a soil nutrient for cropland and reclaimed mining land, or as an aid in contouring mining lands. These provisions set maximum levels for cadmium application and minimum levels for pH of the sludge and soil mixture, and further require that such sludge be treated by a "process to significantly reduce pathogens." These processes include anaerobic digestion, composting, and lime stabilization. Under certain conditions the sludge must also be treated by a "process to further reduce pathogens" such as thermophilic aerobic digestion.[124]

Sewage sludge is frequently incinerated in order to reduce the land disposal requirement. However, as with municipal solid waste, incineration of sewage sludge can be used to produce by-product heat. The heat properties of the sludge can be improved by adding pulverized coal or municipal solid waste in a cocombustion facility. The residual solid waste, e.g., bottom ash, captured fly ash, and scrubber sludge would have to be disposed of in accordance with the regulations mentioned previously.

Other thermal decomposition techniques, such as pyrolytic conversion of sludge to fuel, also can be used to reduce the volume of sludge to be disposed of and produce useful by-products.

Ocean dumping generally has been confined to those coastal cities facing severe land availability problems, such as New York and Philadelphia. However, a statutory ban on ocean dumping is scheduled to go into effect in December 1981. As a result, such cities will have to find some alternative method of disposing of their sewage sludge.

A number of constraints restrict the use of many of these treatment and disposal options. Of particular importance are the potential for microbiological and heavy metals contamination of land, air pollution potential, cost, and citizen opposition to siting disposal facilities. These constraints may be reduced as technology advances, citizens become better educated and the costs of landfill increases.

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[123] Federal Register, Volume 40, pp. 53438-53464, September 13, 1979.

[124] Ibid, p. 53463.

10.6 OTHER SOLID WASTES

HIGHLIGHTS OF SECTION 10.6

- Annual generation of silviculture, agriculture, and animal wastes is expected to increase moderately between 1975 and 2000. These wastes represent significant potential sources of energy.
- Annual demolition waste generation is expected to almost double between 1975 and 2000. Much of this waste is disposed of on land.
- Transportation waste generation is expected to increase slightly between 1975 and 1990. The bulk of this waste is expected to be recycled.

10.6.1 Introduction

Many types of solid waste are generated annually in the United States besides those discussed earlier in this chapter. Wastes covered in this section--silvicultural, animal, agricultural, demolition, and transportation--were chosen for discussion here either because of their potential for contributing to environmental problems or because of their recycling potential. Dredge spoils, a major marine solid waste problem, are addressed in Chapter 9.

10.6.2 Silvicultural Solid Wastes

The two major types of silvicultural solid wastes are logging residues and mill residues. Logging residues are the wastes left over from logging operations; mill residues consist of the wood waste created by lumber, plywood, and woodpulp production, and by production of other primary products.[125]

Based on the production of silvicultural and wood product industries, it has been estimated that about 83 million dry ton equivalents (DTEs)[126] of logging residues and about 86 million DTEs of mill residues were generated in 1970. Of this, a negligible portion of the logging residues and fully 70 percent of the mill residues were reused.[127]

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[125] The MITRE Corporation, Silvicultural Biomass Farms, Volume VI: Forest and Mill Residues as Potential Sources of Biomass, MTR-7347, May 1977.

[126] DTE = dry ton equivalent = a measure of the dry weight of a biomass product.

[127] The MITRE Corporation, Silvicultural Biomass Farms, Volume VI: Forest and Mill Residues as Potential Sources of Biomas, MTR-7347, May 1977, pp. s-4-6.

Based on timber harvest projections, annual logging residue generation is expected to range from 81 to 148 million DTEs in 2000. Using projections of the output of three primary product industries, annual mill residue generation has been projected to range from 88 to 128 million DTEs in 2000.[128]

The disposal of silvicultural solid wastes presents few environmental problems. In fact, the disposal of some silvicultural wastes on land enhances the soil by replacing nutrients in the soil as the wastes degrade.

Silvicultural residues are a major potential fuel source in the United States. Residues can be burned to produce process heat or electricity, thermochemically converted to synthetic gases and liquids, or fermented to produce ethylene gas.[129] Current wood resources, of which silvicultural solid wastes are a large portion, have been estimated at 9 quads annual yield. This total is expected to decline to about 5 quads annually in 1995 and thereafter due to an expected sharp decline in surplus growth.[130]

10.6.3 Animal Wastes

Animal wastes or manure is composed of "lignaceous and fibrous organic matter, nitrogen, phosphorus, potassium, volatile acids, proteins, fats, and carbohydrates."[131] As a result of surface runoff and other transport factors, animal wastes collected on farms, ranches, and feedlots are a major source of surface water contamination by BOD and nutrients.

It has been estimated that more than 2 billion tons of animal wastes are generated annually.[132] Projections of the trends in generation of animal wastes are generally unavailable. However, the constant dollar output of the meat animals and other livestock industry can be used as a surrogate. Under the assumptions of the High Growth Scenario the output of the industry is expected to grow from about 30 billion dollars (1972 constant dollars) in 1975 to about 41 billion dollars by 2000 (about 36 billion dollars under Low Growth assumptions). Therefore, based on these trends, annual animal waste generation can be expected to increase moderately between 1975 and 2000.

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[128] The MITRE Corporation, Silvicultural Biomass Farms, Volume VI: Forest and Mill Residues as Potential Sources of Biomas, MTR-7347, May 1977, pp. s-4-6.

[129] Salo, D.J. and J.F. Henry, "Wood Based Biomass Resources in the United States (Near Term and Long Term Prospects)," Draft, to be published in proceedings of Workshop on Biomass Energy and Technology, sponsored by the Electric Power Research Institute, Palo Alto, California, November 1979, p. 1.

[130] Ibid, pp. 7-10.

[131] Bond, R. and C. Straub, Handbook of Environmental Control, Volume II: Solid Waste, CRC Press, Cleveland, Ohio, 1973, p. 78.

[132] U.S. Environmental Protection Agency, Methods for Identifying and Evaluating the Nature and Extent of Non-Point Sources of Pollutants, U.S. Government Printing Office, Washington, D.C., p. 36.

Animal wastes have numerous beneficial uses, including composting, stock feeding, and pyrolytic conversion to gas. The potential for using animal wastes to produce natural gas substitutes is currently being studied.

10.6.4 Agricultural Wastes

As mentioned in the introduction, EPA estimates that approximately 475 million tons of agricultural waste is generated annually.[133] Assuming that all of this waste is crop-related, the adverse environmental impact of this volume of waste is comparatively small. Since crop-related waste generation is a function of type of crop and acreage under cultivation--neither of which is expected to change sharply between 1975 and 2000 in either scenario--it is not anticipated that annual agricultural waste generation will increase markedly in the near future.[134]

Like silvicultural residues, agricultural wastes can be converted to energy uses through either direct combustion or pyrolytic conversion to natural gas substitutes. A large body of research is under way in the area of energy uses of agricultural wastes.

10.6.5 Demolition Wastes

Demolition wastes are those generated during the destruction of buildings and other structures.[135] At present, the greater portion of these wastes are landfilled, usually in municipal facilities.

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[133] U.S. Environmental Protection Agency, Office of Water and Waste Management, EPA Activities under the Resource Conservation and Recovery Act: Fiscal Year 1978, SW-755, Washington, D.C., March 1979, pp. 1-2.

[134] Total acres in crop production are expected to increase by 18 percent in the High Growth Scenario and to remain constant in the Low Growth Scenario (see Table 6-3).

[135] International Research and Technology Corporation, Forecasts of the Quantity and Composition of Solid Waste, IRT-19300/R-3, June 1979, p. 15.

Annual "net" demolition waste generation has been estimated at 82 million tons in 1971.[136] It is expected that this total will increase to over 150 million tons annually by 1990 under a "business as usual" scenario.[137]

The potential for decreasing demolition waste disposal requirements through recycling is very limited. However, increasing average building lifetimes has been shown to have a dramatic effect on net demolition waste generation.[138] Such an initiative could result in a significant reduction in the landfill requirements of many cities.

10.6.6 Transportation Wastes

Transportation wastes include "product category wastes from automobiles and all other modes of transportation, as well as batteries."[139] Tires are specifically excluded from this definition.

A significant portion of transportation wastes is recycled. Of the 23 million tons of transportation wastes estimated to have been generated in 1971, only about 5 million tons were ultimately disposed of; the rest were recycled. International Research and Technology Corporation has projected that annual transportation waste generation will reach over 28 million tons in 1990. Of this, only 5.9 million tons will require disposal.[140]

Transportation wastes, therefore, are a good example of the extent to which recycling can diminish solid waste disposal requirements.

10.7 IMPACTS AND IMPLICATIONS

The disposal of solid wastes poses numerous potential problems. These problems are not limited to possible adverse environmental and human health impacts but include social and economic problems. The major problems relating to solid wastes are identified and examined in the following sections.

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[136] International Research and Technology Corporation, Forecasts of the Quantity and Composition of Solid Waste, IRT-19300/R-3, June 1979, p. 15. In keeping with the general terminology of SEAS, "net" solid wastes refers to the amount of solid waste generated minus the solid wastes recycled.

[137] Ibid, p. 34.

[138] Ibid, p. 43.

[139] Ibid, p. 15.

[140] Ibid, p. 23.

10.7.1 Ground Water Contamination

Possibly the most critical problem posed by solid waste generation is the potential contamination of ground water by leachate from disposal sites. This contamination has resulted from the disposal of both hazardous and nonhazardous wastes. Ground water is used extensively in the United States as a drinking water supply and, in many areas of the country, it is the only economical source of high-quality drinking water.

In 1977, the EPA Office of Water Supply and Office of Solid Waste Management Programs submitted a report to Congress on the impact of waste disposal practices on ground water.[141] They found that past practices in disposing of wastes have adversely affected ground water quantity and quality in many parts of the country. Of primary concern, both now and in the future, are industrial impoundments or holding ponds and municipal and industrial landfills.

The report also concluded that despite numerous cases of ground water contamination, the overall usefulness of ground water "has not been diminished on a national basis."[142]

The regulations on disposal of solid waste proposed under the Resource Conservation and Recovery Act are designed, in part, to prevent ground water contamination. Design and operation criteria, as well as ground water monitoring requirements for hazardous waste sites, will help ensure that ground water is not routinely contaminated as a result of waste disposal practices in the future. However, there is only a limited capability to model the movement of dangerous compounds from a disposal site through the ground and into ground water. As a result, these criteria will reflect the best engineering judgement available.

However, regulations on future waste disposal will not stop contamination from abandoned sites. Unless these sites, particularly sites containing hazardous wastes, are cleaned up, a continuing decline in the quality of ground water in the United States can be expected.

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[141] U.S. Environmental Protection Agency, Office of Water Supply and Office of Solid Waste Management Programs, The Report to Congress: Waste Disposal Practices and Their Effects on Ground Water, U.S. Government Printing Office, Washington, D.C., January 1977, p. 2.

[142] Ibid.

10.7.2 Public Opposition

Another major problem associated with solid wastes is that communities are becoming more resistant to siting of disposal sites within the community boundaries. This problem is particularly critical for hazardous wastes. This resistance is due primarily to fears on the part of the community that waste disposal sites would decrease land values in the area surrounding the site and would pose a threat to health. The past history of waste disposal does not serve to alleviate these fears. However, safe operation of waste disposal sites may relieve this problem in the future.

Moreover, in the case of mining wastes, for example, public opposition to the aesthetic degradation resulting from waste piles is strong--as evidenced by recent mining reclamation regulations and efforts. Considerable effort will probably have to be undertaken to ensure that solid waste disposal sites are as inoffensive as possible, aesthetically as well as environmentally.

10.7.3 Land Availability

Another problem associated with solid waste disposal is that of land availability. In some areas land values are so high that the cost of land disposal of solid wastes is prohibitive. Certain cities, like New York and Philadelphia, currently dispose of a portion of their municipal solid wastes by ocean dumping. The banning of ocean dumping, effective in 1981, could force such cities to increase recycling of wastes and to utilize other more expensive disposal methods. Nonetheless, land disposal will probably be used as the primary method to dispose of solid wastes in these areas. The resulting conflicts over the use of the land may be severe in some localities.

10.7.4 Site Suitability

In some cases, site suitability may be a problem. Hazardous and special waste facilities cannot be located in environmentally sensitive areas under the proposed regulations. Such areas include:

- o Active fault zones
- o Regulated floodways
- o Coastal high hazard areas
- o 500-year floodplains
- o Wetlands

- Critical habitat areas
- Recharge zones of sole source aquifers[143]

The necessity for such restrictions is fairly evident.

10.7.5 Cost of Disposal

Another major problem associated with solid waste is increased cost of disposal. As a result of the implementation of the Resource Conservation and Recovery Act and the projected increases in solid waste generation, both total costs and costs per unit disposed of are expected to rise in the future. EPA and industry disagree as to the overall economic impact of the Act, with industries' estimates of the cost higher than EPA's estimates. For example, EPA estimates a total annual cost of $750 million for the industries covered by the hazardous waste regulations; industries estimate $25 billion. Considering such a difference of opinion and the preliminary nature of the current regulations, the total cost of the regulations cannot be estimated with any accuracy at present.

10.7.6 Other Problems

A great many other problems are associated with the disposal of solid wastes. These include potential air pollution caused by fugitive dust from waste piles, explosions of trapped gases in landfills, occasional surface water contamination by runoff from waste piles or overflow from holding ponds, and potential releases of pathogens to the environment. The severity of these problems depends heavily on the type of waste and on local environmental factors. However, in some cases, the adverse environmental impacts related to these problems may be significant.

10.7.7 Mitigating Factors

Adverse environmental effects can be considerably alleviated by proper disposal of the wastes and by recycling and other methods. Sanitary landfills, which are the required method of disposal for nonhazardous wastes, are designed to prevent ground water contamination as well as inhibit the growth of bacteria and prevent gas explosions. The quantity of solid wastes that require disposal can be decreased either through process change to decrease the waste-to-product ratio or by increased recycling.

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[143] Fred G. Hart Associates, Impacts of the Designation of Energy-Related Waste as Special Waste, March 1979, p. 2.

Considerable investigation to reduce waste-to-product ratios is being conducted by industry. The environmental and economic implications of future product process changes are almost impossible to assess.

Resource recovery also serves to alleviate the environmental effects of waste disposal. At least one study on the environmental implications of resource recovery has concluded that increased recycling would have positive net environmental and economic benefits. These benefits are realized through decreasing the amount of solid waste disposed of on land and decreasing production requirements by use of recycled products instead of primary products (recycled aluminum instead of bauxite, for example).[144]

10.8 SUMMARY AND CONCLUSIONS

Annual generation of all types of solid waste is expected to increase between 1975 and 2000. Hazardous waste generation may double to 70 million tons (wet) annually by 2000 if the trends of the recent past continue. Even under strong recycling initiatives, more than 350 million tons of industrial and municipal solid wastes would have to be disposed of annually in 1990.[145] Mining waste generation is projected to be over 6 billion tons annually in 2000, as compared with 2 to 3 billion tons in 1975. Even if pollution control regulations do not become more stringent, secondary solid waste generation in 2000 could be as high as 400 million tons annually on a dry-weight basis. It is anticipated, therefore, that total annual solid waste generation will at least double and possibly triple between 1975 and 2000.

There are numerous causes for these increases. The interaction of energy initiatives and environmental regulations result in the increases in generation of secondary wastes related to air pollution. Energy initiatives alone result in the increases in coal and oil shale waste generation projected in the SEAS scenarios. While all of secondary solid wastes come about as the result of environmental regulations, the removal of pollutants from wastestreams is essential to improving the quality of the environment. Economic and population growth fuel the increases in all forms of solid wastes.

The reasons for increases in solid waste generation are complex. No single factor predominates in causing the increases projected.

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[144] The MITRE Corporation, Assessment of the Impacts of Resource Recovery on the Environment, MTR-8033, December 1978.

[145] See Section 10.3. The definitions of municipal and industrial wastes used to derive these projections are not standard.

Therefore, an integrated, comprehensive approach is necessary to alleviate the problems posed by solid waste generation.

The question becomes: How will the United States cope with these increasing amounts of solid waste? Further, to what extent will the regulatory philosophy described in the introduction (see Section 10.1) aid in dealing with the solid waste problem?

Increased recycling and reuse of solid waste will undoubtedly serve to lessen the requirement for disposing of solid waste. It has been shown to have positive net environmental and economic benefits. However, based on current recycling projections, it is unlikely that recycling alone can offset the increase in solid waste generation expected in the period 1975 to 2000, except in certain industries.

Many of the alternative disposal methods are still in design stages or are plagued with problems. Also, a number of the alternative disposal methods are designed only to prevent environmental damage once the waste has been disposed of on land.

The extent to which production process changes will offset the trends in solid waste generation is presently unknown. Perceiving EPA's regulatory philosophy, many industries are investigating the possibilities of process changes to reduce solid waste generation. However, if such changes do not become a reality, more and more land will be needed to dispose of solid wastes, and the problem for some areas of the country will become more severe.

CHAPTER 11
TOXIC SUBSTANCES

HIGHLIGHTS OF CHAPTER 11

- In recent years, on the order of 500 new chemicals have been introduced into commercial production annually, and the 6 percent rate of growth in production in all chemical industries has been twice that of industrial production in general. This trend is projected to continue, with production of some chemicals growing at a much higher rate. Since there are many toxic materials emitted during manufacture and use of these chemicals, the quantity of toxic materials produced may be expected to grow also.

- The mortality rate for all cancers combined has shown a slow, but constant growth in the United States. As a result of cancer onset latency (20 to 30 years), the latest available cancer mortality rates would reflect exposures to carcinogens that occurred soon after World War II. The dramatic increase in U.S. production and use of chemicals since 1950, many of which have been found to be carcinogenic, may eventually be reflected in a rapid acceleration of cancer incidence in the 1980s.

- The market share held by organophosphate insecticides is increasing, while that of organochlorines (chlorinated hydrocarbons) is decreasing. Thus, it would appear that persistent products capable of producing chronic effects are being replaced by those that are more readily degraded. However, these substitute products are often more capable of producing acute toxic effects. Moreover, recent evidence indicates that highly stable breakdown products may be created when these substitute chemicals are degraded in the environment.

- In at least one segment of the plastics industry, vinyl chloride production, Federal regulations to reduce exposure of workers to toxicants seem to have improved production efficiency, while reducing hazardous exposure.

- The principal risk of toxic substances to most people appears to be from chronic toxicity, the effect of prolonged or repeated exposures to chemical agents in the environment. Some occupational situations or accidents result in acute toxic effects, death, or impairment of bodily function from a single or short-term dose.

11.1 INTRODUCTION

Toxic substances are a pervasive environmental problem. Some of the "conventional" pollutants discussed in previous chapters are toxic when emitted or discharged in air, in water, or on land. Other chapters have also dealt with hazardous air pollutants, toxic water pollutants, and hazardous wastes.

However, simply treating the problem of toxic substances as environmental residues does not take into account the other avenues of exposure, including occupational and consumer exposure. Such an approach also ignores the opportunity to deal with toxic substances at their source either by controlling or restricting their production and uses.

Chemical sales in the United States in 1978 exceeded $125 billion[1] and involved some 70,000 different substances.[2] Many of these chemicals exhibit little or no toxicity, and even a very toxic substance presents little risk if it is isolated from the environment. Nevertheless, there is growing evidence of health and environmental risk in our "chemical society," both from brief, often accidental, exposure to high levels of a toxic substance and from prolonged exposure in a "normal" environment to low levels of one or several toxic substances.

A major problem in public policy, then, is protecting the public from exposure to toxic substances. Environmental policy decisions require identification of toxic substances, their toxic properties and their exposures to humans and the environment, and an assessment of the resulting risk. Identification of toxic substances does not mean simply looking at synthetic chemicals, for our diverse natural environment provides many toxic materials--asbestos, lead, and aflatoxin, to name only three; and exposure to these materials increases during industrial extraction and production. Production of toxic heavy metals has grown steadily, with mercury and cadmium consumption increasing by about 70 percent between 1948 and 1968[3] and remaining fairly constant since then.[4] Lead consumption has risen steadily over the same 30-year period.[5]

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[1] "Facts and Figures for the U.S. Chemical Industry," Chemical and Engineering News, June 11, 1979, p. 47.

[2] Council on Environmental Quality, Environmental Quality--1978, U.S. Government Printing Office, Washington, D.C., p. 178.

[3] Council on Environmental Quality, Toxic Substances, U.S. Government Printing Office, Washington, D.C., April 1971.

Concurrently, evidence of the health and environmental dangers associated with certain widely used substances has been accumulating. For example:

- Kepone, an insecticide that has been implicated in nervous system disorders, was discharged into the James River from the mid-1960s until 1975, resulting in closure of the fisheries there.
- Vinyl chloride, a chemical intermediate widely used in the plastics industry, has been implicated as causing liver cancer in industrial workers.
- Polychlorinated biphenyls (PCBs) are toxic and possibly carcinogenic chemicals widely used in the electrical industry. They are found at levels exceeding 1 ppm in the tissues of almost 40 percent of the U.S. population.[6]

The toxic substances problem is compounded because the health and environmental risks posed by a chemical are often not discovered until after the chemical has been in widespread use and is considered important to agriculture, industry, and/or consumers. This fact highlights the importance of adequate and timely test procedures in avoiding future environmental problems related to toxic substances.

Public concern over increased use of toxic substances resulted in a 1971 report on toxic substances by the President's Council on Environmental Quality (CEQ).[7] That report provided the impetus for legislative proposals that ultimately led to enactment of the Toxic Substances Control Act (TSCA) of 1976 (PL 94-469). That Act gave EPA direct control over most commercially produced (non-drug, non-pesticide) toxic chemicals, not just their discharges and emissions.

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[4] U.S. Department of the Interior, Bureau of Mines, Minerals Yearbook, 1969-1978.

[5] Ryan, J.P. and J.M. Hague, "Lead--1977," Mineral Commodity Profiles, MCP-9, U.S. Department of the Interior, Bureau of Mines, December 1977.

[6] Council on Environmental Quality, Environmental Statistics 1978, National Technical Information Service, March 1979, p. 131.

[7] Council on Environmental Quality, Toxic Substances, U.S. Government Printing Office, Washington, D.C., April 1971.

Similar concerns also led to EPA regulation of pesticides under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1947 (PL 80-104), as amended in 1972, 1975, and 1978.

Control of toxic substances is at once one of the highest priorities at EPA and one of the most ambitious tasks the Agency faces. In the words of Administrator Douglas Costle,[8]

> I consider the implementation of the Toxic Substances Control Act one of the most difficult challenges and important priorities now facing EPA. We have neglected the subtle but lethal effects of chemicals for decades. Now, we must extend the frontiers of scientific knowledge to evaluate what those risks really are and find ways to control them.

11.2 LEGISLATION AND REGULATION

11.2.1 Introduction

Control of toxic substances has a fairly recent history. Since 1947, pesticides sold in interstate commerce have been regulated under the Federal Insecticide, Fungicide, and Rodenticide Act, but almost 30 years elapsed before the Toxic Substances Control Act was passed to deal with other toxic chemicals.

The 1971 CEQ report on toxic substances identified three major concerns:

- The existence of a gap in government authority to control production of toxic substances not included under food and drug laws
- The difficulty of monitoring and setting emission limits on substances that enter the environment only in very small amounts
- The fact that, after final use, toxic materials generally enter the environment--via land, water, or air

As the CEQ report was being drafted, the Nixon Administration proposed legislation to address these concerns. Five years of Congressional attention finally led to passage of TSCA.

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[8] Costle, D., Statement at Public Meeting on Implementation of the Toxic Substances Control Act, Washington, D.C., March 22, 1977.

11.2.2 The Toxic Substances Control Act

The Toxic Substances Control Act authorized EPA to obtain production and test data on chemical substances from industry and to regulate these substances as necessary to avoid "...an unreasonable risk of injury to health or the environment." If inadequate test data are available, EPA may require chemical manufacturers or processors to perform the necessary tests at their own expense. The manufacturer must notify EPA 90 days prior to commercial production of a new chemical substance. Regulatory actions possible under the Act range from requiring labeling, to limiting, or prohibiting the manufacture, processing, distribution, use, or disposal of a toxic substance. TSCA also allows information gathering by EPA inventories, health and safety studies, and occupational exposures. Finally, TSCA is unique among environmental laws because it is designed to be a gap-filling law. That is, generally speaking, EPA is to defer to other agencies for action if those agencies have statutory authority under another law to deal with the problem at hand. Also, if EPA itself has sufficient authority to deal with the problem under some other law (such as the Clean Air Act, RCRA, etc.), EPA is to use that other authority.

11.2.3 Pesticide Regulation

The Federal Environmental Pesticide Control Act of 1972 (PL 92-516), amending the Federal Insecticide, Fungicide, and Rodenticide Act, marked several major changes in the law EPA then administered. One new requirement called for reregistration of pesticides already being used. Those pesticides with "unreasonable adverse effects" would be registered for "restricted use" by certified applicators only. If use restriction still did not prevent adverse effects, the Agency was authorized to suspend or to cancel a pesticide's registration.

The Reorganization Plan No. 3 of 1970 also delegated to the Administrator of EPA the authority, under the Federal Food, Drug, and Cosmetic Act, as amended (21 USC 346, 346a, 348), to determine tolerances for pesticide chemicals in or on raw agricultural commodities and to monitor compliance with the tolerances and the effectiveness of surveillance and enforcement.

When the Federal Insecticide, Fungicide, and Rodenticide Act was amended in 1975 (PL 94-140) and again in 1978 (PL 95-396), Congress granted legislative relief to expedite registration and certification under the law. EPA was directed in 1975 to pay close attention to the impact of the proposed action on the agricultural economy. Provision was also made for the Secretary of Agriculture to comment publicly on all regulations before they were promulgated. Under the

Act, industry is required to provide testing data to EPA to confirm the safety of pesticides for registration. The amendments clarified the rules for releasing these data and determining compensation for sharing these data between formulators and producers. As it now stands, if EPA uncovers evidence of possible environmental or health hazard in its review of a pesticide, a public notice, "Rebuttable Presumption Against Registration" (RPAR), is issued (40 CFR 162.11). The manufacturer or other interested parties must then rebut the presumption of risk before the pesticide can be registered.

In implementing the amended Act, EPA has given priority to filling gaps in the test data on pesticides in use before 1972, and to expediting registration of new chemicals that provide substitutes for old chemicals taken off the market.

If the reregistration process were to consider each of the 1,400 pesticide active ingredients now in general use, it would take the Agency at least 10 years to meet its responsibilities under the law. Standards are planned for only 514 active ingredients, for many of the 1,400 chemicals originally identified are not in any currently registered product, are inert, or are similar in nature. Also, a setting of generic standards for the 514 active ingredients obviates the need to individually consider each of the approximately 33,000 pesticides in current use.

11.2.4 Other Laws and Other Agencies

Table 11-1 lists the various laws under which EPA regulates toxic substances. Since TSCA is a gap-filling law, deferring to other applicable statutes, the first laws in the table are of considerable regulatory importance. Thus Section 112 of the Clean Air Act has provided regulatory authority for hazardous air pollutants, and Section 307 of the Clean Water Act, for toxic effluents. Activities under these sections currently demand much of the Agency's resources. In contrast to Chapter 4, Air Pollutants, and Chapter 6, Water Pollutants, of this Environmental Outlook, later portions of this chapter will emphasize the substances considered under these two sections of the Clean Air and Clean Water Acts, and will relate the actions of the Agency to these sections.

Section 112 of the Clean Air Act prescribed procedures for the Administrator of EPA to list hazardous air pollutants, to establish a National Emission Standard for Hazardous Air Pollutants (NESHAP) for each pollutant, and to issue information on pollution control techniques for these air pollutants. The National Emission Standards for Hazardous Air Pollutants apply to both new and existing emission

TABLE 11-1
EPA AUTHORITY AND REGULATION OF TOXICS

LAW	SECTION	PRESENT LISTS
Clean Air Act of 1970, as amended 1977	Sec. 108 Criteria Air Pollutants	Six traditional pollutants, as listed by the Administrator (25 November 1971).[a]
		Administrator added lead as a criteria pollutant (5 October 1978).[b]
	Sec. 112 Hazardous Air Pollutants	Beryllium, asbestos, mercury (6 April 1973).[c]
		Vinyl chloride (21 October 1976).[d]
		Benzene (8 June 1977).[e]
	Sec. 122 Certain Unregulated Pollutants	Cadmium, arsenic, polycyclic organic matter (soot), radioactive releases, in 1977, sulfates, to be considered for inclusion under sec. 108 or 112 (in the law).
Federal Water Pollution Control Act of 1972, as amended 1978	Sec. 301 "Priority List"	65 items in a consent decree[f] that have been interpreted as 129 substances. Criteria documents for these will be published soon (in the law).
	Sec. 304 Conventional Pollutants	Biological oxygen demand, suspended solids, fecal coliform, pH, and others the Administrator may identify, but not thermal pollution. Criteria for these are in (g) (in the law).

(continued)

TABLE 11-1 CONTINUED

LAW	SECTION	PRESENT LISTS
	Sec. 307 Toxic Substances Standards	Aldrin, DDT, Toxaphene, and benzidene (12 January 1977).[h]
		PCBs (2 February 1977).[i]
	Sec. 311 Oil and Hazardous Substances	A few hundred substances which are hazardous in spills (13 March 1978).[j]
	Sec. 316 Thermal Discharges	Discharges from power plants (8 October 1974).[k]
Federal Insecticide, Fungicide and Rodenticide Act, as amended 1972, 1975 and 1978	Sec. 3 Registration and Classification	The Special Pesticide Review Office of the Office of Pesticide Programs selects ingredients under the "RPAR" process.[l] All pesticides whose use is restricted are listed in regulation (Became effective 4 August 1975).[m]
	Sec. 6 Cancellation	Cancellation usually applies to a specific set of uses, or the inadequacy of a label. About 40 substances have had agency cancellation actions against them (Under previous laws ability to cancel was limited).[n]

(continued)

TABLE 11-1 CONTINUED

LAW	SECTION	PRESENT LISTS
Safe Drinking Water Act of 1974	Sec. 1412(a) Interim Primary Standards	9 inorganics, 6 pesticides.[o] 3 categories of radioactive substances (24 December 1975).[p]
	Sec. 1412(b) Interim Secondary Standards	Guidelines for chloride, color, copper, corrosivity, foaming agents, iron, manganese, odor, pH, sulfate, TDS, and zinc (19 July 1979).[q]
Marine Protection Research and Sanitation Act, as amended 1974	Sec. 102 and 105 Ocean Dumping	Materials and trace contaminants prohibited in ocean dumping (11 January 1977).[r]
Resource Conservation and Recovery Act of 1976	Sec. 3001 Hazardous Materials	Categories of hazardous substances and processes for the purpose of classifying wastes (Proposed 18 December 1978).[s]
Toxic Substances Control Act of 1976	Sec. 4(e) Priority List	A list of no more than 50, updated twice yearly, of categories of substances recommended for testing by the Interagency Testing Committee (First version 4 October 1977, current revision 1 June 1979).[t]

(continued)

TABLE 11-1 CONTINUED

LAW	SECTION	PRESENT LISTS
	Sec. 6(e) Polychlorinated Biphenyls	Bans on manufacture and distribution (in the law).[u]
	Sec. 8(b) Inventory	The inventory of chemicals now manufactured are exempt from "pre-manufacture notification" (1 June 1979).[v]
	Final rule by FDA, EPA (TSCA Sec. 6), and CPSC	Uses of haloalkanes (e.g. freon) in consumer products (17 March 1978).[w]

[a] 40 CFR 50

[b] 43 FR 46246

[c] 40 CFR 61.2-5

[d] 40 CFR 61.6,7

[e] 42 FR 29332

[f] Natural Resources Defense Council v. Train, No. 75-172, (D.C.D.C.) (8 ERC 2120), June 8, 1976.

[g] U.S. Environmental Protection Agency, Quality Criteria for Water, U.S. Government Printing Office, Washington, D.C., July 1976.

[h] 40 CFR 129.4

[i] 40 CFR 129.4

(continued)

TABLE 11-1 CONCLUDED

[j] 40 CFR 116.4

[k] 40 CFR 122.1

[l] Pesticides that the Special Pesticide Review Office has selected for "rebuttable presumption against registration" (RPAR) process are listed periodically in the "Special Pesticide Review Status Report," an unnumbered document.

[m] 40 CFR 162.31

[n] A "quick reference guide" of these actions and their dates is as follows: U.S. Environmental Protection Agency, Scientific Support Branch, Pesticides and Toxic Substances, Enforcement Division, *Suspended and Cancelled Pesticides*, Washington, D.C., May 1978. Since this pamphlet was issued, two additional substances have been cancelled. They are, with the dates of the actions, Endrin, 25 July 1979; and Chlorobenzolate, 13 February 1979.

[o] 40 CFR 141.11

[p] 40 CFR 141.15

[q] 44 FR 42195-202

[r] 40 CFR 227

[s] 43 FR 58946

[t] The first list was published in both the Federal Register (42FR55026) and TSCA Interagency Testing Committee, *Initial Report of the TSCA Interagency Testing Committee to the Administrator, Environmental Protection Agency*, EPA 560-10-78/001, January 1978. Each subsequent list was also accompanied by a similar report. The most recent list, in 44 Federal Register 31866-889, lists all substances recommended to date.

[u] 43 FR 31514

[v] U.S. Environmental Protection Agency, *A Toxic Substances Control Act Initial Inventory*, Vol. I-VI, GPO 055-007-00004-7, 055-007-00003-9, U.S. Government Printing Office, Washington, D.C.

[w] 43 FR 11301

sources. Section 122 directed the Administrator to consider radioactive pollutants, cadmium, arsenic, and polycyclic organic matter for inclusion in the Section 112 list. Eleven toxic substances (asbestos, arsenic, beryllium, cadmium, chromium, lead, mercury, nickel, polychlorinated biphenyls, polycyclic organic matter, and vanadium) were appraised as candidates for the first list.[9] The initial list was limited to asbestos, beryllium, and mercury; standards for these were promulgated in April 1973 (38 FR 8820). Vinyl chloride standards were added in October 1976 (41 FR 46560), and benzene was added to the list in June 1977 (42 FR 29332). Arsenic and cadmium are currently being considered for the list. Several other substances are now undergoing health assessments for toxicity in air and may be added later to the list. New regulatory activities under Section 112 are awaiting the Administrator's final action on an Agency airborne carcinogen policy.

Section 307 (Toxic and Pretreatment Effluent Standards) of the Clean Water Act of 1977 (PL 95-217) specifically identified an initial list of 65 toxic pollutants, or combinations of pollutants, and authorized the Administrator to revise the list from time to time. Each pollutant listed is subject to point source effluent limitations by application of best available technology economically achievable. In addition, the Administrator may establish a more stringent effluent standard (or prohibition). Finally, the Administrator may establish pretreatment standards, or new source performance standards (NSPS), for any source introducing pollutants into a publicly owned treatment works.

The initial list and standards of Section 307 of the Clean Water Act of 1977 derive from a 1976 settlement agreement in U.S. District Court, in four cases challenging EPA's regulation of toxic pollutants under the Federal Water Pollution Control Act.[10] EPA subsequently expanded the list by selecting organic compounds representative of the classes of compounds in the initial list of 65. The selection process produced a new list of 129 "priority pollutants" (114 organic compounds, 13 metals, asbestos, and cyanide). The Agency is determining the presence of these pollutants in industrial effluents. Water quality criteria for all 65 classes of priority pollutants have been listed for public comment, and final criteria are now in preparation. A recent memorandum opinion and court order modified the settlement agreement by setting a schedule for promulgation of regulations for 34 industrial categories (latest regulation--May 8, 1981) and extending EPA's deadline for meeting all of its obligations under the agreement until June 30, 1984.[11]

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[9] U.S. Environmental Protection Agency, Office of Enforcement, National Emission Standards for Hazardous Air Pollutants--A Compilation, EPA-340/1-79-006, April 1979, p. I-2.

[10] Natural Resources Defense Council v. Train, No. 75-172 (D.C.D.C.) (8 ERC 2120), June 8, 1976.

EPA's actions are also coordinated with those of other agencies through the Interagency Regulatory Liaison Group (IRLG). The IRLG currently consists of representatives from the Food and Drug Administration (FDA) (which regulates food, drugs, and cosmetics); the U.S. Consumer Product Safety Commission (which regulates dangerous consumer products); the Occupational Safety and Health Administration (OSHA) (which regulates toxic substances in the workplace); the Food Safety and Quality Service of the U.S. Department of Agriculture (USDA); and EPA. The recent publication of an IRLG work group report, Scientific Bases for Identification of Potential Carcinogens and Estimation of Risks, is a major step toward the goal of a common, government-wide carcinogens policy (44 FR 39858).[12] Additional steps await the October 1979 conclusion of the public comment period. The report itself has no regulatory status, but it may be used as a basis for action by individual agencies.

Other activities on toxics are carried out by a 17-agency Toxic Substance Strategy Committee formed in response to the directive in President Carter's 1977 Environmental Message to coordinate Federal research and regulatory activities concerning toxic chemicals.[13] The Interagency Testing Committee, which determines priorities for the testing of chemicals for toxicity, is discussed later in this chapter.

11.3 DATA SOURCES AND QUALITY

Information presented here includes data on trends in production in the chemical industry, selected high-volume toxic organic chemicals, inorganic chemicals (heavy metals), and pesticides production. Most forecasts of future trends are based on the SEAS High Growth Scenario and are consistent with SEAS-derived projections presented elsewhere in this report. (See Chapter 2 for a description of the SEAS Scenarios.) Other historical and prospective data are taken from industrial and trade compilations.

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[11] Natural Resources Defense Council v. Costle, No. 75-172 (D.C.D.C.) (12 ERC 1833), March 9, 1979.

[12] "Report on Carcinogen Identification, Human Risk Assessment Issued by IRLG," Chemical Regulation Reporter, Vol. 2, 1979, p. 2039.

[13] Carter, J., Message to the Congress of the United States, The White House, May 23, 1977.

11.4 ORGANIZATION OF CHAPTER

The remainder of this chapter is divided into three major sections: identification of toxic substances, trends in production, and impacts and implications.

11.5 IDENTIFICATION OF TOXIC SUBSTANCES

11.5.1 Introduction

The intent of TSCA, FIFRA, and other related laws is to protect public health and the environment against unreasonable risk of injury posed by the release of economically justified toxic substances into the environment. To meet the concerns expressed through these laws, appropriate regulatory actions must be based on adequate knowledge of the toxicity and environmental fate of individual chemicals and chemical mixtures. The enormous number of chemicals on the market, and the large number added each year, make acquisition of such knowledge a formidable task. Given limited resources, it is necessary to preselect chemicals prior to undertaking extensive toxicity testing and environmental fate studies. Selection criteria must be based on limited data, but the data must afford some estimate of the potential risks posed by a chemical.

11.5.2 Toxicity Versus Risk

Toxicity is an inherent characteristic of a chemical substance that defines the degree of adversity an organism will experience when exposed to the substance at a certain dose level. Developing adequate protection of public health and the environment requires more than just knowledge of a chemical's toxicity; knowledge of the risk posed by the chemical is also needed. Risk refers to the likelihood that a chemical will be present at a certain exposure level that will cause dosages deleterious to an organism. A chemical can have relatively high inherent toxicity but present a low risk if likely exposures result in insufficient dosages to produce any toxic effect. Therefore, to identify and regulate toxic chemicals, criteria must be established that adequately assess risk by determining the potential exposures to a chemical as well as its inherent toxicity.

11.5.3 Exposure

To determine which chemicals should receive priority for testing and possible regulation, rough estimates of likely exposures can be obtained from several sources:

- Current or proposed production rates

- Data on probable environmental releases from production, use, and disposal through mass-balance engineering assessments

- Study of basic chemical/physical properties compared with well-characterized chemicals, to indicate the possible transformation/transportation the substance would undergo in the environment

Such information may also identify those chemical agents whose releases are likely to be difficult to control but are not ubiquitous in the environment; these agents should be given special consideration when priorities are set for testing and assessing risks.

In response to TSCA, the Interagency Testing Committee was created to establish a priority list of chemicals to be recommended to EPA for additional testing and possible regulation. Choices for the list have been based upon comparisons of production volumes, estimated environmental releases, and likely population exposures; substances already regulated, chemically inert, or previously well characterized were deleted. The list was then refined in light of toxicological considerations. (See footnote t, Table 11-1.)

11.5.4 Toxicity

Acute Versus Chronic Toxicity

The traditional technique in toxicity study is the lethality dose determination, a short-term animal test that determines the dose of a chemical agent which results in the death of 50 percent of the test animal population (LD_{50}) within a specified time after administration. However, in general, release of toxic agents into the environment is not likely to result in exposures capable of producing acute effects. Such acute exposures are apt to be limited to occupational situations or result only from major accidents such as spills.

Prolonged or repeated exposures to low levels of chemical agents in the environment can have deleterious, but often highly subtle, effects on an entire population. These types of effects constitute chronic toxicity, which acute toxicological methods such as the LD_{50} test cannot identify. This is readily illustrated by the observation that body organs found to be targets in acute experimentation are not always the targets identified following repeated exposures to low doses of the same chemical in chronic experimentation. Cause-effect relationships are often not as apparent in chronic exposures as they are in studies of acute toxic exposure. The observable toxic response may be the result of continual storage of low doses of the chemical until a toxic threshold is breached; the action of its metabolic products in the body, with subsequent mobilization and redistribution; the repeated and additive insults on target organs, enzymes, or other body systems; or a long-delayed response to a single or time-limited exposure. The insidious effects of low-level, chronic exposures to toxicants may result in behavior modification, mutagenic alterations, somatic cellular damage, loss of reproductive capabilities, cancer initiation, or chronic cellular damage to any or all of the organs and systems of the body. Moreover, the complexity of the possible chronic effects posed by toxic chemicals can be greatly increased when one looks beyond single-species impacts to assess the potential ecological consequences of these chemicals in the environment. There is a need for tests to screen chemicals for their chronic toxicity and these tests need to be sensitive to predicting possible ecological as well as single-species impacts.

Screening

It is a substantial undertaking to identify among the thousands of chemicals produced, those chemicals with the potential for eliciting any of the adverse responses mentioned above. Preliminary screening can be done by comparing a compound's chemical/structural properties with those of well-characterized toxicants. But even with such screening, a large number of chemicals would need additional testing, and many chemicals with important toxicological implications could be missed.

A number of short-term tests have been developed for use in predicting carcinogenicity and for possible use in the rapid screening of chemical compounds. These short-term tests are primarily limited to identification of mutagenic toxicity which frequently correlates with mammalian carcinogenicity. Neither complete identification of all toxicants having chronic effects, nor the extrapolation of results gained through short-term testing to possible effects in humans, is accepted practice, although initiatives are well underway to explore the potential. Moreover, short-term tests for other chronic effects, such as behavior modification or certain organ disorders, are limited or non-existent. Thus, "the state-of-the-art and our understanding of short-term tests are not sufficiently advanced to allow such tests to be used in place of long-term tests."[14] However, our understanding is improving with an expectation that short-term testing can be used to identify, at least qualitatively, long-term health effect potential. Also, EPA's Office of Research and Development has developed several short-term tests to screen chemicals for their potential to be ecologically disruptive; these tests are now undergoing extensive "round-robin" testing and validation. The expense of complex and/or long-term animal studies requires continued utilization of these short-term assays and efforts to continue their development.

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[14] U.S. Environmental Protection Agency, Support Document Test Data Development Standards: Chronic Health Effects Toxic Substances Control Act, Section 4, EPA-560/11-79-001, May 1979, p. I-21.

11.6 TRENDS

11.6.1 Introduction

The environmental outlook for toxic substances will remain incomplete, as well as unclear, until improved toxicity testing and risk assessment methods have been developed for analyzing the hazards posed by the thousands of chemicals yet to be tested. However, a limited assessment of the environmental outlook for toxic substances can be achieved by:

1. Following trends in the production and environmental releases of known or highly suspected hazardous substances, thus indicating potential environmental exposure levels and resulting impacts.

2. Identifying and defining political, social, or economic trends that may impact on current or proposed production rates of chemicals. Such information may result in resetting priorities for chemicals to be tested or possibly regulated.

3. Following trends in relevant indicators of environmental and public health, such as accumulations of toxicants in soil, sediment, wildlife, food, or human tissues; incidence rates of birth defects, cancers, spontaneous abortions, or other health disorders; and species diversity, populations of critical species, or energy flow/nutrient cycling of crucial ecosystems.

This discussion is limited primarily to trends in the production of known or highly suspect hazardous chemical substances. These trends are presented in four categories: chemical industry production (overall chemical activity); high-volume toxic organic chemicals; inorganics (heavy metals); and pesticides. The last section on implications discusses trends of relevant indicators of environmental and public health--such as accumulation of toxic residues in various parts of our environment and incidence of cancer.

11.6.2 Trends in Chemical Industry Production

Over the past quarter century, production growth rates for basic chemicals, chemical products, and synthetic material industries have been very large. About 50,000 synthetic chemicals are currently produced and used in significant quantities,[15] and in recent years EPA's premanufacturing notice program under TSCA has identified about 500 new chemicals introduced annually. Although the number of toxic chemicals is limited, aggregated chemical industry production figures may indicate considerable potential exposure to toxic chemicals in the environment.

In 1971, the Council on Environmental Quality estimated that synthetic organic chemicals production increased at a 15 percent average annual rate from 1958 to 1968.[16] More recent data[17] indicate that the annual rate of growth in production in all chemical industries averaged 6 percent from 1968 through 1978, twice the growth rate for total industrial production. Over that period, production of plastics averaged an 11 percent annual growth rate. The rate of growth in production of organic chemicals in the 50 highest production chemicals increased an average of 5.7 percent a year to 172 billion pounds in 1978.[18]

Production rates in the chemical industries are shown in Figure 11-1. Production data for basic chemicals, synthetic materials (polymers), chemical products, and total manufacturing are plotted for 1968 through 1978. In addition, production data from the SEAS High Growth Scenario for chemicals, miscellaneous chemical products, and plastic materials and resins project continued high growth rates in these industries. Past and future strong growth in the chemical industries, stronger than the growth of total manufacturing, is clearly indicated.

Aggregated production data give at best a qualitative measure of the magnitude of potential toxic materials problems. However, estimates of future toxics hazards based on industrial production data are a good initial step in assessment. They also indicate the quantities of materials that must be dealt with under TSCA or RCRA guidelines.

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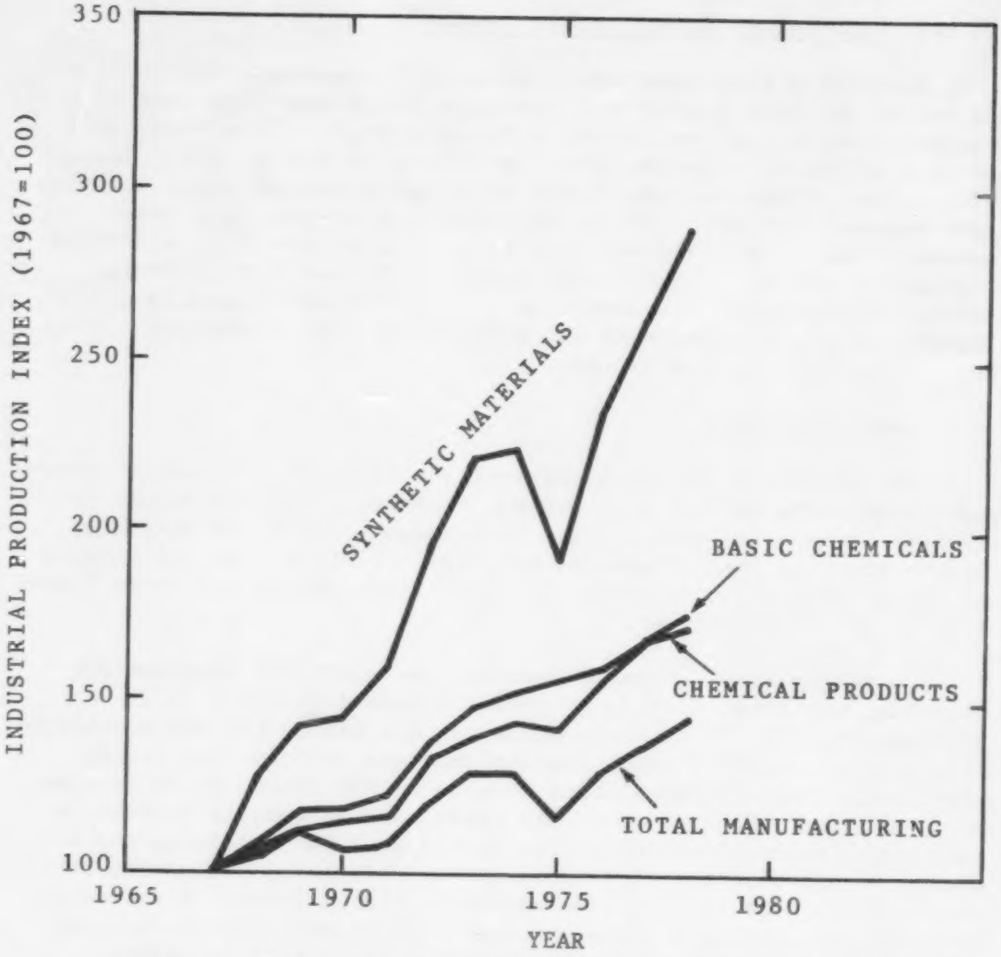
[15] Ames, B.N., "Identifying Environmental Chemicals Causing Mutations and Cancers," *Science*, Vol. 204, 1979, p. 587.

[16] Council on Environmental Quality, *Toxic Substances*, U.S. Government Printing Office, Washington, D.C., 1971, p. 3.

[17] "Facts and Figures for the U.S. Chemical Industry," *Chemical and Engineering News*, June 11, 1979, p. 36.

[18] Ibid, p. 35.



Source: "Facts and Figures for the U.S. Chemical Industry", Chemical and Engineering News, June 11, 1978, p. 36. Used with permission.

FIGURE 11-1
SOME CHEMICAL INDUSTRY PRODUCTION TRENDS

11.6.3 High Volume Toxic Organic Chemicals

Historical production data, along with production trends projected by the SEAS High Growth Scenario, for benzene and several organic chemicals closely tied to the production of the ubiquitous polymer polyvinyl chloride (PVC), are shown in Figure 11-2. These high-volume chemicals were chosen as examples because vinyl chloride (the monomer from which PVC is produced) and benzene have been demonstrated to be toxic and have been the subjects of considerable regulatory action. The PVC intermediate ethylene dichloride is currently undergoing assessment as a suspected carcinogen in air. Significantly, regulation is not diminishing either measured production or projected trends.

Vinyl Chloride

The production of vinyl chloride has risen at a 9 percent average annual rate for the past decade, reaching 7 billion pounds in 1978.[19] Production data for the past three years[20] and SEAS High Growth Scenario projections for polyvinyl chloride, the end product of essentially all vinyl chloride production, indicate an even faster growth rate in the future.

In making vinyl chloride from the raw materials ethylene and chlorine, the first step is to make ethylene dichloride (1,2-dichloroethane). This intermediate is then passed through a dehydrochlorination reaction which removes hydrogen chloride and yields vinyl chloride. Polymerization results in PVC resin, which is commonly sold as a fine powder. The resin is subsequently fabricated into a multitude of products from pastes or films following the addition of plasticizers (for upholstering materials, wallpaper, etc.) to rigid products such as pipe and house siding formed by extrusion. Toxicity concerns arise from exposure to ethylene dichloride, vinyl chloride, hydrogen chloride, plasticizers (typically phthalate esters), and PVC. Effective emissions controls would limit exposure to the first three compounds to workers in the production facility, controlled under OSHA regulations.

Evidence for vinyl chloride's toxicity and carcinogenicity in both man and animals has accumulated over the quarter century of the compound's production. By the mid-1970s, a statistically significant incidence of liver and lung cancers in vinyl chloride workers had

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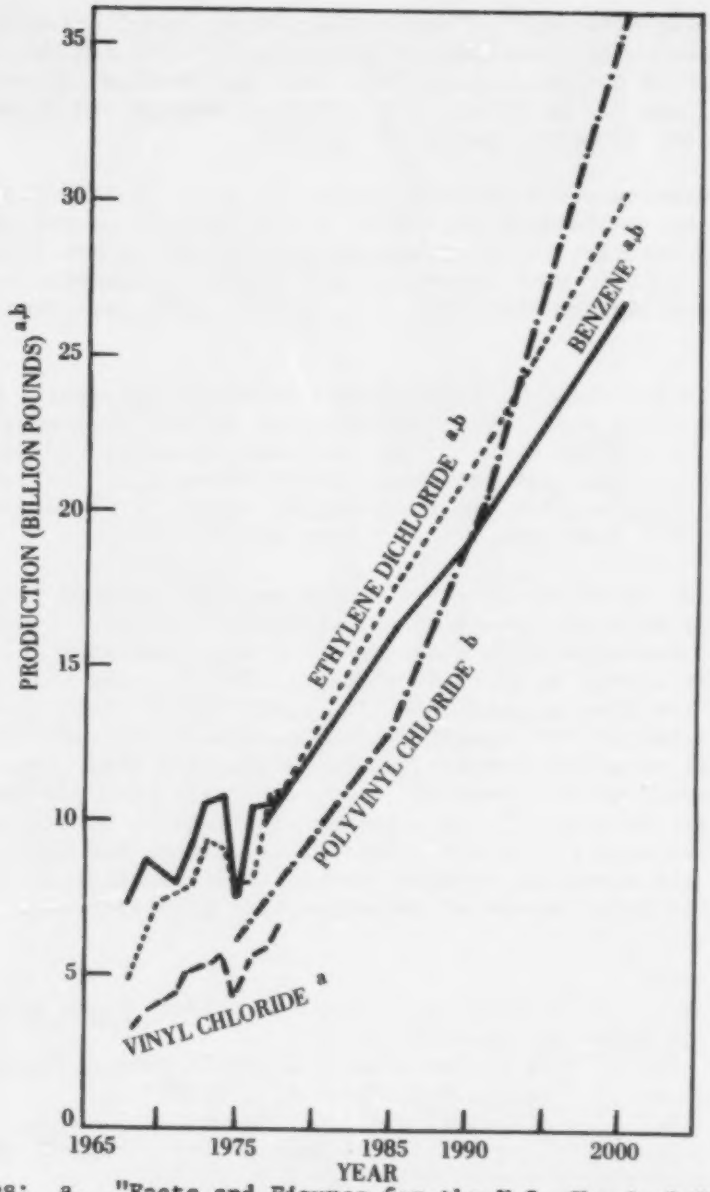
[19] "Facts and Figures for the U.S. Chemical Industry," Chemical and Engineering News, June 11, 1979, p. 35.

[20] "Key Chemicals: Vinyl Chloride," Chemical and Engineering News, June 18, 1979, p. 9.



Sources: a. "Facts and Figures for the U.S. Chemical Industry", Chemical and Engineering News, June 11, 1979, p. 37. Used with permission.

b. SEAS, High Growth Scenario, Inforum Output.

FIGURE 11-2

PRODUCTION OF SELECTED HIGH VOLUME ORGANIC CHEMICALS

clearly been demonstrated.[21] Shortly thereafter, vinyl chloride was demonstrated to be a mutagen in Salmonella.[22] The regulatory process was set in motion, and in 1974, OSHA set permissible worker exposures at 1 ppm for an 8-hour time weighted average and 5 ppm averaged over any 15-minute period.[23]

EPA promulgated vinyl chloride standards under Section 112 of the Clean Air Act on October 21, 1976. EPA's regulations for emissions of vinyl chloride during manufacturing operations set limits on emissions from certain unit operations and associated process equipment; these controls are therefore more specific than OSHA regulations.

Since 1974 the chemical industry has developed systematic procedures for decreasing vinyl chloride emissions and for meeting the standards set by EPA and OSHA.[24] The equipment is monitored and the workers' procedures are observed. After emission points are identified, methods are devised for reducing emissions to levels that satisfy regulatory standards.

Since 1974, the chemical industry has met EPA and OSHA standards by retrofitting existing plants and by carefully engineering new plants. It is estimated that these measures have increased the capital cost of the plants by 20 to 40 percent. However, the side benefits derived were greater plant efficiency and higher plant operating rates.[25] As a result, PVC plastics are more than cost-competitive with many rival materials and are widely desired for many uses. Continuing production increases of 10 to 12 percent per year for the next 5 years are forecast.[26] This growth will require enlargement of present production plants and construction of some new plants. Concurrently, the number of workers exposed to vinyl chloride will increase and the total amount of emissions will also increase.

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[21] Tamburro, C.H., "Health Effects of Vinyl Chloride," Texas Reports on Biology and Medicine, Vol. 37, 1978.

[22] Ames, B.N., "Identifying Environmental Chemicals Causing Mutations and Cancers," Science, Vol. 204, 1979, p. 587.

[23] Bochinski, J.H., K.S. Schoultz, and J.A. Gideon, "Pollution Control Practices--Meeting Emission Standards for Acrylonitrile," Chemical Engineering Process, Vol. 75, 1979, p. 53.

[24] Ibid.

[25] Ibid.

[26] "Key Chemicals: Vinyl Chloride," Chemical Engineering News, June 18, 1979, p. 9.

Compounds and processes in PVC production are under continuing EPA scrutiny. Vinyl chloride, ethylene dichloride, and phthalate esters are identified under Section 304 of the Clean Water Act as priority pollutants, and water quality criteria have recently been proposed for vinyl chloride (44 FR 15926). EPA studies of industrial effluents have identified phthalate esters as being ubiquitous, ethylene dichloride in 50 percent of all industrial categories and 6.5 percent of effluent samples, and vinyl chloride in only 0.2 percent of samples.[27] Clearly, vinyl chloride emissions are being controlled, but the risk of exposure to the other chemicals must be assessed.

Benzene

Benzene production exceeded 11 billion pounds in 1978, reflecting average annual growth of 4 percent over the last decade.[28] SEAS projections indicate a continuation of that growth rate.

Benzene, unlike vinyl chloride, is used by consumers as well as industry. Products for consumer use include laboratory solvents, paint strippers, rubber cement, gasolines, engine oil flush, and gas stove and lantern fuels.[29,30] Thus the potential for public exposure is great, and the Consumer Product Safety Commission, EPA, and OSHA have all been concerned with benzene's potential toxicity.

Evidence is substantial that benzene in concentrations found in the workplace has caused diseases of the blood and bone marrow, particularly leukemia.[31] Consequently, benzene was added to the list of hazardous air pollutants under Section 112 of the Clean Air Act in June 1977. At present, benzene is the only substance on that list that has not been regulated; but EPA has prepared a health effects assessment, an environmental exposure assessment, and a population risk assessment. One report suggests that a benzene regulatory standard will be proposed in early 1980.[32]

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[27] Schaffer, R.B. and J. Riley, Occurrence of Priority Pollutants in Industrial Effluents, paper presented to the Air Pollution Control Association, Gainesville, Florida, February 15, 1979.

[28] "Facts and Figures for the U.S. Chemical Industry," Chemical and Engineering News, June 11, 1979, p. 35.

[29] "Gas Stove, Lantern Fuel, Engine Oil Flush Most Affected by Benzene Ban," Chemical Regulation Reporter, Vol. 2, 1979, p. 1783.

[30] Young, R.J., R.A. Rinsky, P.F. Infante, and J.K. Wagoner, "Benzene in Consumer Products," Science, Vol. 199, 1978, p. 248.

[31] U.S. Environmental Protection Agency, Office of Research and Development, Office of Health and Ecological Effects, Assessment of Health Effects on Benzene Germane to Low-Level Exposure, EPA-600/1-78-061, September 1978.

Activities under Section 307 of the Clean Water Act have listed benzene as a priority pollutant (43 FR 4108), resulted in proposed water quality criteria for benzene as a potential carcinogen (44 FR 15926), and identified benzene in effluent in 29 percent of samples and 25 of 32 industrial categories surveyed.[33]

A proposed OSHA standard for benzene was struck down by the Fifth Circuit Court of Appeals on October 5, 1978. The appeal has now been taken to the Supreme Court, where oral arguments will be heard during the October 1979 term.[34] The deadline for a proposed ban of benzene in consumer products by the Consumer Product Safety Commission has been extended.[35]

The regulatory experience with vinyl chloride and benzene suggests that, while regulating industrial exposure is fairly easy, regulating exposure of the general population is more difficult. If vinyl chloride is a valid indicator, regulation need not impair, but indeed may enhance, industrial productivity and profitability.

11.6.4 Inorganic Chemicals (Heavy Metals)

Historical U.S. demand and projected trends for three nonferrous metals (mercury, lead, and cadmium) are shown in Figure 11-3. These substances have stimulated regulatory actions by their well-publicized adverse human health effects. The press has reported the health hazards of ingestion of lead contained in paints by children, and the ingestion of mercury in seafood, as well as the effects of occupational exposures.

Figure 11-3 illustrates that:

- Despite fluctuations over the last 10 years, demand for mercury and cadmium has slowly declined, while demand for lead has increased

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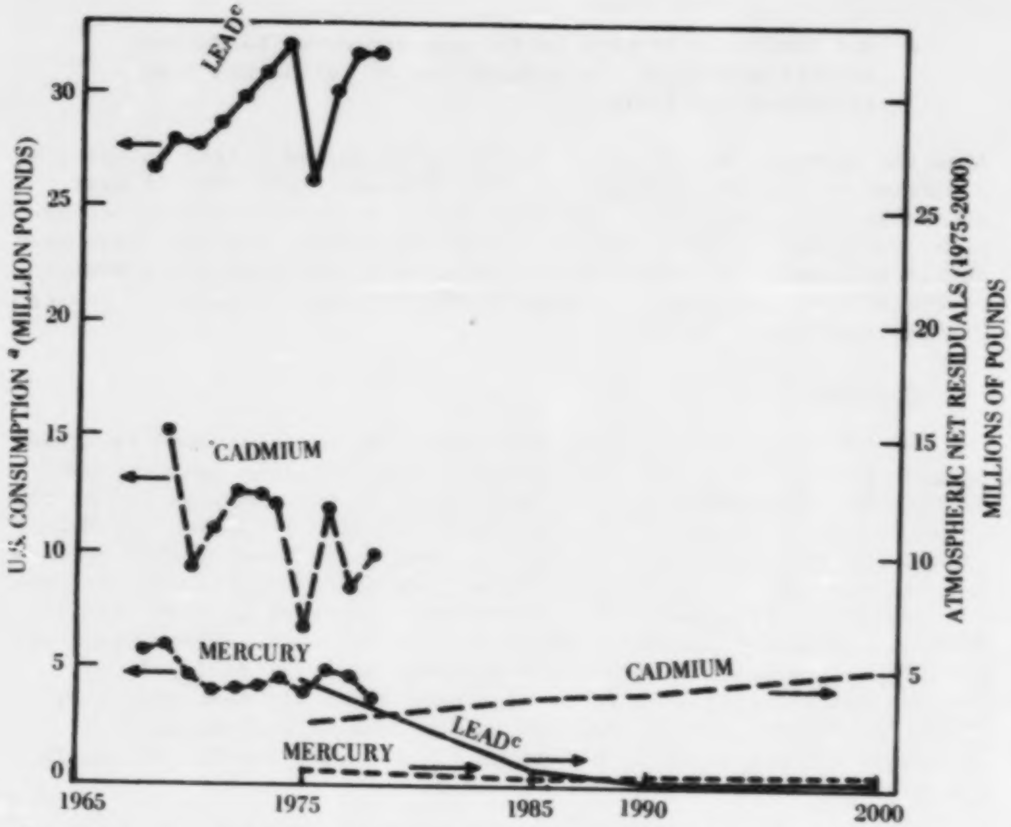
[32] "First EPA Air Emission Standard to Be Proposed in Early 1980," Chemical Regulation Reporter, Vol. 3, 1979, p. 730.

[33] Schaffer, R.B., and J. Riley, Occurrence of Priority Pollutants in Industrial Effluents, paper presented to the Air Pollution Control Association, Gainesville, Florida, February 15, 1979.

[34] "Benzene Case Will Be Argued During Supreme Court's Fall Term," Chemical Regulation Reporter, Vol. 2, 1979, p. 2245.

[35] "Proposed Benzene Ban Deadline Extended Six Months by CPSC," Chemical Regulation Reporter, Vol. 2, 1978, p. 1285.



Sources: a. Cadmium: Personal Communication, John M. Lucan, Bureau of Mines, U.S. Department of the Interior, September 1979. Bureau of Mines, Lead and Mercury Minerals Yearbooks, U.S. Department of Interior, September 1979.

b. SEAS High Growth Scenario, Air Particulates.

c. Lead is in units of hundred million pounds.

FIGURE 11-3
SELECTED HEAVY METALS—UNITED STATES CONSUMPTION
AND ATMOSPHERIC RESIDUALS

- Net residuals of lead in air are projected to decline dramatically with the elimination of tetraethyl lead in automotive fuels

Also the presence of all three metals as dissolved solids in water is projected to decline markedly by 1985 with implementation of best available technology under the Clean Water Act; pretreatment regulations for electroplaters (major sources of metals in water) have recently been set. All three metals have been regulated for a number of years under the permit program of the National Pollutant Discharge Elimination System (NPDES).

Mercury

Of the three metals under discussion, mercury has been regulated longest by EPA. Together with asbestos and beryllium, mercury was designated a hazardous air pollutant in 1971 under Section 112 of the Clean Air Act. In April 1973, National Emission Standards for Hazardous Air Pollutants were applied to stationary sources that process mercury ore, and to those that use mercury chlor-alkali cells to produce chlorine and alkali metal hydroxides. Mercury is also identified as a priority pollutant under Section 307 of the Clean Water Act of 1977, and since its high vapor pressure makes it particularly onerous in the workplace, it is regulated as an air contaminant by OSHA (29 CFR 1910.1000). Mercury in the form of organic mercury compounds are particularly hazardous for they are readily stored in the tissues of humans and other animals.

The principal categories of demand for mercury are caustic soda and chlorine production, electrical applications, instruments, and paints. In the last 10 years, use of mercury in the pulp and paper industry has been eliminated; it has declined in caustic soda and chlorine production, but has increased in electrical applications. Solid-state devices may obviate the need for mercury in many electrical applications, but as long as mercury battery usage grows, demand for mercury will remain strong.

Lead

In 1973, EPA initially promulgated regulations for "phase-down" of lead in gasoline. A 1975 suit brought by the Natural Resources Defense Council (NRDC) against EPA[36] resulted in categorizing lead as a criteria air pollutant under Section 108 of the Clean Air Act.

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[36] Natural Resources Defense Council, et al. v. Train, 411 F. Supp. 864 (S.D.N.Y., 1976).

EPA's final air quality criteria and proposed regulations for state implementation plans were promulgated on October 5, 1978 (43 FR 46246). Lead is also identified as a priority water pollutant, and on March 15, 1979, notice was given of proposed criteria (44 FR 15926).

OSHA's attempts to set a standard for exposure to lead in the workplace are currently in litigation. The standard set in November 1978 was immediately challenged by both industry and labor. Oral arguments in the case are slated for October 1979 in the D.C. Court of Appeals. Recently the Lead Industries Association has petitioned this same court for a review of the lead criteria setting under the Clean Air Act.[37]

As is discussed in Chapter 4, following phase-down of lead in gasoline, lead emissions from motor vehicles in most areas should be drastically reduced. Emissions from other sources (e.g., metal processing, electricity generation) are expected to increase by the year 2000.

Cadmium

Regulation of cadmium is more recent. Chronic and acute human exposures to cadmium via inhalation and ingestion are known to cause a variety of serious health effects such as pulmonary emphysema and kidney damage. Comparisons of renal cadmium levels in specimens taken in human autopsies in this and the last century suggest that cadmium body burdens are increasing.[38] There is also evidence that cadmium may be a carcinogen.[39,40] In March 1979, EPA gave notice of proposed criteria under the Clean Water Act (44 FR 15926) and has been conducting health effects studies and carcinogen assessments since 1977 to develop criteria under Section 122 of the Clean Air

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[37] "Clean Air Act Lead Standard Challenged for Alleged Improprieties," Chemical Regulation Reporter, Vol. 3, August 3, 1979, p. 744.

[38] Elinder, C.G. and T. Kjellstrom, "Cadmium Concentration in Samples of Human Kidney Cortex from the 19th Century," Ambio, Vol. 6, 1977, p. 270.

[39] U.S. Environmental Protection Agency, Office of Research and Development, Cadmium Health Effects: Implications for Environmental Regulations, External Draft, Review Copy, July 1979, p. 27.

[40] Smith, R.J., "Toxic Substances: EPA and OSHA Are Reluctant Regulators," Science, Vol. 203, 1979, p. 28.

Act, under Section 405 of the Clean Water Act, and under Section 4004 of the Resource Conservation and Recovery Act.[41]

Although cadmium consumption in the United States has gradually declined, SEAS projections of increased lead and zinc smelting suggest that net cadmium emissions will increase gradually. Also, cadmium is found in elevated levels in sewage treatment sludge from many sources. In addition, cadmium and its salts are involved in new solar cell and battery technologies. If one of these new technologies becomes prominent, cadmium demand and resulting residuals may rise sharply.

11.6.5 Pesticides

Figure 11-4 illustrates apparent domestic (U.S.) consumption of insecticides. Several trends may be identified for the years 1965-1980. Note that the 1980 numbers represent a range for projections from 1974. Total insecticide apparent domestic consumption is increasing only slightly, about 1 percent per year. This trend reflects stable acreages in crops and emphasis upon lower insecticide usage or controlled application.

The market share held by organophosphates is increasing, while that of organochlorines (chlorinated hydrocarbons) is decreasing. Restrictions on chlorinated pesticides (DDT, Aldrin/Dieldrin, 2,4-D, etc.) have been largely responsible for this shift.

Inorganic insecticides (calcium and lead arsenates), continuing a 30-year trend,[42] are falling to insignificant levels of consumption following their replacement by organics, their regulation as contaminants in drinking water and air, and manufacturers' concern for potential EPA actions under FIFRA (issuance of Rebuttable Presumption Against Registration notices).

The most significant expansion is in carbamate consumption, about 8 percent per year. Carbamates, like organophosphates, are acetylcholinesterase inhibitors that are less persistent than organochlorines both in the physical environment and in organisms. Thus, although they may be more or less toxic than organochlorines, they exhibit much less biomagnification in the food chain.

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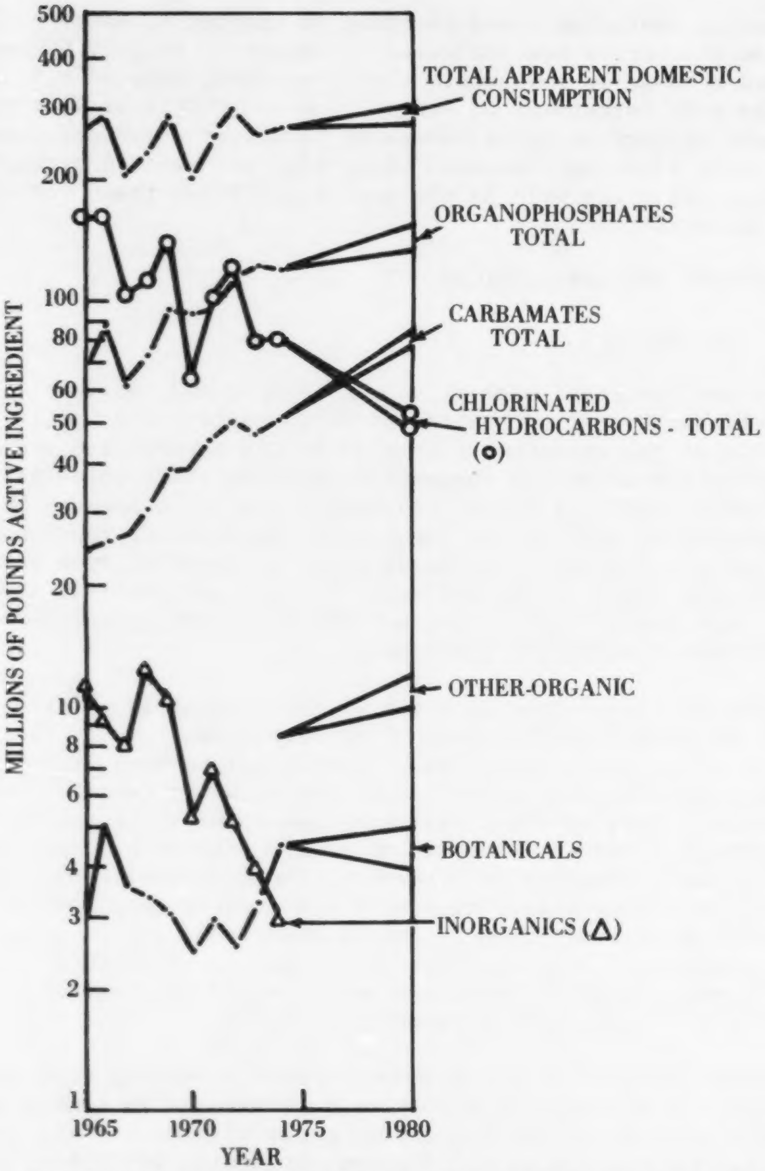
[41] U.S. Environmental Protection Agency, Office of Research and Development, Cadmium Health Effects: Implications for Environmental Regulations, External Draft, Review Copy, July 1979, Preface.

[42] Stanford Research Institute, Chemical Economics Handbook, 573.2400A, August 1972.



Source: Stanford Research Institute, Chemical Economics Handbook, 573.3007, July 1976. Used with permission.

FIGURE 11-4
APPARENT DOMESTIC CONSUMPTION OF INSECTICIDES

Another pesticide trend is cited in Chapter 6, Water Pollutants. Fungicide discharges are projected to increase, largely because of increased acreage in soybeans. (See Chapter 6, Section 6.3.3.) Also, the U.S. Department of Agriculture and Office of Technology Assessment project major increases in herbicide usage over the next twenty years with the expansion of no-till or low-till agricultural practices. This may well be the most significant trend for the rest of the century.

11.7 IMPACTS AND IMPLICATIONS

11.7.1 Introduction

Any environmental outlook on the impacts and implications of toxic substances must be considered as incomplete and highly tentative. Few of the chemicals currently on the market have undergone the testing necessary for adequately defining their potential risk to either human health or the environment. The environmental impacts of toxic substances will not be clear until methods for rapid and complete toxicity testing of at least major chemical classes have been developed and used. A limited assessment of the possible impacts can be made from trends seen in production and environmental releases of known or highly suspected toxicants.

Known toxicants have been identified from their deleterious effects on workers in the occupational environment where the potential exists for acute exposures. Even larger numbers of toxicants have been identified in animal experimentation or isolated cell system studies. Many of these toxicants are known to be released into the environment and have been found in the ambient air and drinking waters of human communities. However, the concentrations of these toxicants in the general environment are usually very low in comparison to the dosages utilized in animal studies or realized in occupational exposures. High environmental levels of toxicants would be likely to occur only as results of major accidents, and would be generally localized to small geographic areas.

Direct evidence of any adverse effects resulting from the low, but chronic, environmental exposures to toxicants is sparse and often inconclusive. Nevertheless, various kinds of data are now available which associate environmental factors, including pollution, with cancer incidence. Increased congenital abnormalities in the young of parents who have been exposed to certain toxicants in the environment have also been noted. Moreover, since many toxicants are highly stable in the environment, the possibility exists for physical accumulation within various environmental compartments to levels posing hazards of acute toxicities. Of even greater concern is the ability of certain classes of toxicants to accumulate through food chains as a result of their persistent nature and their affinity for biological tissues. The data that describe these impacts of toxic substances are presented in the following sections with an attempt to describe what the implications of these impacts could be in regard to the environmental outlook.

11.7.2 Accumulation and Bioconcentration

As stated previously, various chemicals have been found to be highly stable in the environment, by virtue of their resistance to chemical, photochemical, or microbial degradations. The chemicals most often cited for their environmental persistence are primarily chlorinated hydrocarbons (or organochlorines), such as the pesticides Mirex, Dieldrin, and DDT, and the PCB dielectric fluids used in capacitors and transformers. The resistant nature of these chemicals to environmental degradation can result in their physical accumulation within various environmental compartments to levels which may pose hazards of toxicity.

Many of the persistent organochlorines, including those mentioned above, also possess an inherent affinity for biological tissue, and as a result of natural cycling of nutrients through the food chain, these chemicals tend to bioconcentrate in the tissues of species representing the apex of food chains. The extent of this bioconcentration phenomenon is indicated by comparing concentrations of organochlorine pesticide residues in agricultural soils (see Table 11-2), where these compounds were intentionally released, with the concentrations found in wildlife samples of fish and birds (Tables 11-3 through 11-6). Man, as the apex species of several food chains, has not escaped the accumulation of these chemical residues in his tissues (see Table 11-7). Levels of certain chlorinated hydrocarbons recently found in human mother's milk are shown in Table 11-8. Other organochlorines (such as Mirex, Kepone, and Toxaphene) not assayed in these particular studies are also capable of accumulating in food chains.

Many of the organochlorines that bioconcentrate through food chains have been shown to be carcinogenic in animal studies and have been proven mutagenic in isolated cell assays. These residues may also pose hazards of acute toxicities to wildlife when the organism's fat stores containing the residues are mobilized for nutrition during migration, hibernation, or other stresses of low food intake or high activity. Bioaccumulation of DDT residuals has also been

TABLE 11-2
PESTICIDE RESIDUES IN AGRICULTURAL SOILS[a], FY 1969-FY 1974[b]
(ppm dry weight, geometric mean)

	FY1969	FY1970	FY1972	FY1973	FY1974
DDTR[c]	.0148	.0125	.0131	.0100	.0073
Aldrin	.0031	.0034	.0024	.0021	.0008
Dieldrin	.0088	.0104	.0097	.0090	.0066
Aldrin/Dieldrin	.0119	.0138	.0121	.0111	.0074
Toxaphene	.0025	.0011	.0045	.0035	.0017
Chlordane	.0038	.0046	.0035	.0034	.0006
Heptachlor	.0008	.0013	.0010	.0006	.0003
Heptachlor Epoxide	.0014	.0017	.0010	.0012	.0010
Total: Chlordane, Heptachlor, Epoxide	.0060	.0076	.0055	.0052	.0019

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[a] Data were collected from 34 states, except that for FY 1972. Heptachlor and Heptachlor epoxide data were collected from 37 states.

[b] Not measured in 1971.

[c] DDTR includes DDT and its related derivatives.

Source: Adapted from the Council on Environmental Quality, Environmental Statistics 1978, National Technical Information Service, March 1979, p. 128.

TABLE 11-3
TOXIC RESIDUES IN U.S. FISH, 1969-1977 AS EVIDENCE OF BIOCONCENTRATION
(ppm, geometric mean)

Year	DDT[a]	Toxaphene	Dieldrin[b]	PCBs
1969	1.06	N.A.	.08	1.06
1970	.87	N.A.	.08	1.07
1971	.67	<.05	.04	.90
1972	.59	.11	.07	1.07
1973	.40	.11	.04	.71
1974	.44	.11	.08	.96
1975[c]	-	-	-	-
1976/77	.36	.35	.06	.87

NOTE: Freshwater fish samples collected by Fish and Wildlife Service personnel in all 50 states as part of the National Pesticide Monitoring Program. Two-thirds of the fish sampled are bottom-dwelling species such as carp, suckers, and catfish. The remaining one-third of the fish sampled are predacious species such as trout, walleye, bass, and bluegill. The whole fish is analyzed, not just the fillet.

[a] Includes DDT and its derivatives.
[b] Includes Aldrin.
[c] Not measured in 1975.

Source: Adapted from the Council on Environmental Quality, Environmental Statistics 1978, National Technical Information Service, March 1979, p. 180.

TABLE 11-4
TOXIC RESIDUES IN U.S. WATERFOWL BY FLYWAY, 1965-1976 AS EVIDENCE OF BIOCONCENTRATION
(ppm)

Year	DDE[a] Pacific	Central	Mississippi	Atlantic
1965/66	0.65[b]	0.15[b]	0.25[b]	0.70[b]
1969	0.71	0.30	0.40	1.03
1972	0.34	0.15	0.37	0.44
1976	0.22	0.28	0.25	0.32

Year	Dieldrin Pacific	Central	Mississippi	Atlantic
1965/66	<.01	<.01	<.01	<.01
1969	0.02	0.02	0.04	0.05
1972	0.01	0.02	0.02	0.02
1976	0.02	0.03	0.05	0.06

Year	PCBs Pacific	Central	Mississippi	Atlantic
1965/66	N.A.[c]	N.A.	N.A.	N.A.
1969	0.20	0.20	0.44	1.29
1972	0.11	0.10	0.66	1.24
1976	0.16	0.15	0.23	0.52

NOTES: (1) Data measured as mean, parts per million (ppm) wet weight.

(2) Residues are measured in wings of adult mallards sampled in the continental United States as part of the National Pesticide Monitoring Program. Samples are drawn from mallard wings sent to the Fish and Wildlife Service by sportsmen. Residue level in wings reflect those found in the rest of the body. Over 5,000 duck wings are analyzed during each year's collection period.

[a] DDE is a derivative of DDT.

[b] Includes DDT and its metabolites.

[c] N.A. = Not available.

Source: Adapted from the Council on Environmental Quality, Environmental Statistics 1978, National Technical Information Service, March 1979, p. 182.

TABLE 11-5
TOXIC RESIDUES IN U.S. STARLINGS, 1967-1976 AS EVIDENCE OF BIOCONCENTRATION
(ppm, geometric mean)

Year	DDE[a]	Dieldrin	PCBs
1967/68	.579	.084	b
1970	.355	.036	.358
1972	.387	.035	.215
1974	.229	.019	.068
1976[c]	.254	.039	.243

NOTE: Samples collected through trapping or shooting throughout the continental United States by Fish and Wildlife Service personnel as part of the National Pesticides Monitoring Program. Feet, beaks, wingtips, and skins were removed and the remainder of the sample was analyzed. About 1,400 starlings are analyzed each year. Statistics are presented in terms of wet weight.

[a] DDE is a derivative of DDT.
[b] Not measured.
[c] Preliminary data.

Source: Adapted from the Council on Environmental Quality, Environmental Statistics 1978, National Technical Information Service, March 1979, p. 184.

TABLE 11-6
POPULATION CHARACTERISTICS AND TOXIC RESIDUES IN BROWN PELICANS IN CALIFORNIA, 1969-1975 AS EVIDENCE OF BIOCONCENTRATION

	Population Characteristics			Toxic Residues[a]		
Year	No. Nests Built	No. Young Fledged	No. Young Fledged Per Nest	No. Eggs in Sample[b]	DDT[c] (ppm)	PCBs (ppm)
1969	1,125	4	.004	28	1204	200
1970	727	5	.007	N.A.[d]	N.A.	N.A.
1971	650	42	.065	N.A.	N.A.	N.A.
1972	511	207	.405	10	>221	N.A.
1973	597	134	.255	4	183	43
1974	1,286	1,185	.922	39	97	146
1975[e]	N.A.	N.A.	N.A.	4	113	120

NOTE: Areas studied were Southern California and Northwestern Baja California including Anacapa and Santa Cruz Islands and Isle Coranado Norte. Concentrations of toxic residues are in eggs.

[a] Geometric mean concentration in eggs, ppm lipid weight basis.
[b] Intact eggs only.
[c] Includes DDT and all its derivatives.
[d] Not available.
[e] Anacapa Island only.

Source: Adapted from the Council on Environmental Quality, Environmental Statistics 1978, National Technical Information Service, March 1979, p. 185.

TABLE 11-7
CHLORINATED HYDROCARBON RESIDUES[a] IN HUMAN FAT AS EVIDENCE OF BIOCONCENTRATION
(average of 168 Canadian samples)

Compound	Amount[b] (μg/kg Wet Weight)	Percentage of Samples Containing Residues
PCB	907	100
Hexachlorobenzene	62	100
BHC (Lindane)	65	88
Oxychlordane	55	97
Trans-nonachlor	65	99
Heptachlor epoxide	43	100
Dieldrin	69	100
p,p'-DDE	2095	100
o,p'-DDT	31	63
p,p'-TDE	6	26
p,p'-DDT	439	100

[a] Most are carcinogens.

[b] Values are means.

Source: Adapted from Ames, B.N., "Identifying Environmental Chemicals Causing Mutations and Cancers," Science, Vol. 204, 1979, p. 587. Used with permission.

TABLE 11-8
SOME PESTICIDES IN THE MILK OF 1,400 WOMEN

Compound	Number Positive (percent)	Mean of Positive (μg/kg fat)[a]	Maximum (μg/kg fat)
DDE	100	3521	214,167
DDT	99	529	34,369
Dieldrin	81	164	12,300
Heptachlor epoxide	64	91	2,050
Oxychlordane	63	96	5,700
β-BHC	87	183	9,217
PCBs	30[b]	2,076	12,600

[a] 4.5 percent = mean fat content.

[b] 99 percent detectable PCBs: (30 percent = >1,100 μg per kilogram of fat; 1,038 women.) Environmental Protection Agency, 1977.

Source: Adapted from Ames, B.N., "Identifying Environmental Chemicals Causing Mutations and Cancers," Science, Vol. 204, 1979, pp. 582-593. Used with permission.

associated with dysfunction of reproductive physiology in predatory birds, through eggshell-thinning.[43]

Concern about the buildup of organochlorines in man and the environment and their associated adverse effects has led to a cancellation of most uses of DDT, Aldrin, Dieldrin, Kepone, and Mirex, and to termination of PCB production. Use restrictions, coupled with increasing insect resistance, have resulted in a continual decrease in organochlorine insecticide production with an associated increase in the production of other types of insecticides, particularily the organophosphate compounds. This trend would be further heightened if any major uses of Toxaphene, the most heavily used insecticide in the United States, were curtailed as a result of recent tests indicating mutagenicity[44] and carcinogenicity.[45]

The environmental outlook in this area indicates likely improvement but remains tentative. The restrictive use of many major organochlorine pesticides should continue the trend toward decreasing residues in human food (Table 11-9) and in human tissues (Table 11-10), and in wildlife (see Tables 11-3 through 11-6). On the other hand, PCBs have become widespread throughout the population, although tissue from over half of those individuals sampled contained residuals of less than 1 ppm (Table 11-11). The termination of PCB production may result in a gradual decline of residuals similar to that observed with DDT residues. However, PCBs were primarily used as dielectric fluids in capacitors and transformers. As these closed-system products reach their limit of useful life, of approximately 10-30 years, further PCB contamination may occur if the PCB fluid is reused or disposed of improperly.

Domestic restriction of production or use of persistent chemicals does not preclude their use and subsequent environmental release on an international scale. Developing countries struggling to meet their food needs are likely to continue to rely on the older, cheaper, more persistent pesticides.

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[43] Risebrough, R.W., J. Davis, and D.W. Anderson, "The Biological Impact of Pesticides in the Environment," in Gillett, J.W., ed., Environmental Health Series 1, Oregon State University, 1970, pp. 40-53.

[44] Hooper, N.K., B.N. Ames, M.A. Salem, and J.E. Casida, "Toxaphene, a Complex Mixture of Polychloroterpenes and a Major Insecticide, Is Mutagenic," Science, Vol. 205, 1979, p. 591.

[45] U.S. Department of Health, Education, and Welfare, National Cancer Institute Carcinogenesis Technical Report, Series 37, Publication NIH 79-837, Washington, D.C., 1979.

TABLE 11-9
DIET INTAKE OF PESTICIDES[a]
FY 1966-FY 1974
(mg/day)

Year	Pesticides, Total[b]	Organochlorine Insecticides	Organophosphorus Insecticides	Carbamates	Herbicides
FY1966[c]	0.156	0.112	0.010	0.026	0.008
FY1967	0.116	0.082	0.017	0.013	0.004
FY1968	0.084	0.073	0.005	0.002	0.004
FY1969	0.078	0.057	0.015	0.003	0.003
FY1970	0.067	0.045	0.018	0.003	0.001
FY1971	N.A.[d]	N.A.	N.A.	N.A.	N.A.
FY1972	N.A.	N.A.	N.A.	N.A.	N.A.
FY1973	0.061	0.017	0.013	0.030	0.001
FY1974[e]	0.052	0.024	0.012	0.012	0.001

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[a] Values are determined from analyses of 12 categories of foods prepared from "market basket" samples collected in major U.S. cities and designed to simulate the diet of a 15-20-year-old male.

[b] Rounding may create inconsistencies in addition.

[c] Data for FY 1966 may not include all pesticides.

[d] N.A. = Not available.

[e] Total for FY 1974 does not include 0.004 mg/day of miscellaneous pesticides.

Source: Adapted from the Council on Environmental Quality, Environmental Statistics 1978, National Technical Information Service, March 1979, p. 127.

TABLE 11-10
TOTAL DDT EQUIVALENT RESIDUES IN HUMAN ADIPOSE TISSUE FROM GENERAL POPULATION, UNITED STATES

Years	Residues (ppm lipid weight)[a]				
	FY1970	FY1971	FY1972	FY1973	FY1974
Birth-14	4.47	3.74	3.03	2.63	2.32
15-44	7.53	8.29	7.23	6.23	5.46
45 and above	8.88	8.64	7.96	7.13	6.97
National Summary	7.88	7.95	6.88	5.59	5.02

NOTE: Total DDT equivalent = (o,p'-DDT + p,p'-DDT) + 1.114 (o,p'-TDE + p,p'-TDE + p,p'-DDE + o,p'-DDE).

[a] Residues expressed are geometrics means.

Source: Adapted from Kutz, F.W., A.R. Yobs, S.C. Strassman, and J.F. Viar, "Pesticides in People," Pesticide Monitoring Journal, Vol. 11, 1977, p. 63. Used with permission.

TABLE 11-11

RESIDUES OF PCBs IN HUMAN TISSUE, FY 1972-FY 1975

Year	Sample Size	PERCENT DETECTED WITH PCBs					
		Total[a]	<1 ppm	1-2 ppm	1-3 ppm	>2 ppm	>3 ppm
FY1972	4,100	74.0	15.5	N.A.[b]	50.7	N.A.	7.9
FY1973	1,277	75.5	40.2	29.6	N.A.	5.5	N.A.
FY1974	1,047	90.9	50.6	35.4	N.A.	4.9	N.A.
FY1975	779	94.3	56.1	N.A.	27.6	N.A.	10.7

[a] Rounding may create inconsistencies in addition.
[b] N.A. = Not available.

Source: Adapted from the Council on Environmental Quality, Environmental Statistics 1978, National Technical Information Service, March 1979, p. 131.

The outlook could be significantly altered by substitution of new chemicals for the organochlorines. For example, a current large overcapacity in bromine production could urge utilization of new brominated compounds as substitutes for the organochlorine chemicals. But, since bromine and chlorine are both halogens, organic compounds containing bromine may have physical/chemical properties such that they could pose the same hazards of accumulation, bioconcentration, and toxicity as the original chlorinated compounds.

Other problems may result from the continuing trend toward replacing organochlorine insecticides with other types of pesticides, particularly with organophosphate compounds. The organophosphate insecticides are among the most toxic, and of all the pesticides used, these have been most often cited in both accidental mass poisoning,[46] and in occupational toxicity problems.[47] Moreover, it was recently suggested that certain degradation products of organophosphate insecticides could be highly stable, resisting further degradation and possibly accumulating to significant levels in the environment.[48] For these reasons, phasing out the persistent organochlorine compounds does not necessarily mean that the environment will be protected.

11.7.3 Effects on Reproductive Functions

Toxicants may affect the reproductive process in various ways--many so subtle that only large-scale population studies over several generations could detect them. Such reproductive effects, however, can hold much graver consequences for the continuation of a species or even an entire ecosystem than any other acute or chronic toxic effect. Moreover, reproductive effects may occur at much lower doses than those required to produce other acute or chronic adverse effects. A toxicant may alter behavior in a manner which impedes normal mating or parental behavior or may lead to dysfunction of reproductive physiology. Examples include the observed decrease of sperm production in human males occupationally exposed to the fumigant DBCP and the egg-shell thinning found in various predatory birds that accumulated certain organochlorine pesticides in their tissues.

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[46] U.S. Department of Health, Education, and Welfare, Secretary's Commission on Pesticides, Report of the Secretary's Commission on Pesticides and Their Relationship to Environmental Health, U.S. Government Printing Office, Washington, D.C., 1969.

[47] California Department of Public Health, Occupational Diseases in California Attributed to Pesticides and Other Agricultural Chemicals, 1969, Bureau of Occupational Health and Environmental Epidemiology, Sacramento, California, 1969.

[48] Daughton, D.G. and D.P.H. Hsieh, "Parathion Utilization by Bacterial Symbionts in a Chemostate," Applied and Environmental Microbiology. Vol. 34, 1977, p. 175.

Of the approximately 3 million children born in the United States each year, about 200 thousand (almost 7 percent) have birth defects. More than 560 thousand (almost 19 percent) of all pregnancies terminate in spontaneous abortions, stillbirths, or miscarriages caused by maldevelopment.[49] At this time, it is impossible to determine the contributions of toxicants to these totals. Nevertheless, the often-found high sensitivity of the reproductive system to toxicants and the increasing list of compounds shown to be mutagenic should cause concern about their possible contribution to these figures.

During pregnancy, maternal exposure to chemicals such as the chlorinated dioxin TCDD may possibly result in fetal death, and spontaneous abortion in humans, as has been shown in animal studies. Toxicants may cause subtle or profound birth defects through toxic action on developing organs and tissues. Some observed effects are reduced birth weight in offspring of smoking parents; massive dysfunctioning of the nervous system in children whose mothers were exposed during pregnancy to methylmercury by eating contaminated fish; and gross body deformation in the progeny of mothers who received doses of the tranquilizer Thalidomide during pregnancy. After birth, the developing young can be highly susceptible to the toxic actions of chemicals from exposure through the mother's milk. This is the reason for studies such as found in Table 11-8.

Perhaps the greatest concern is the potential for certain chemicals to alter the genetic makeup of progeny, and subsequent continuation of these alterations through several generations. A number of chemicals have given positive results in mutagenic screening assays, and perhaps many of these may be able to reach and mutate the germ cells as well as the somatic cells.[50] The cost of these chemically caused mutagenic effects to future generations may be much more than our current understanding can assess. Human genetic defects are not easy to attribute to a specific cause, and a considerable increase in birth defects might occur without causal attribution. Moreover, many consequences of a general increase in gene mutations in the germ line might be subtle, e.g., decreased intelligence.

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[49] March of Dimes National Foundation, Facts, National Foundation, New York, 1975.

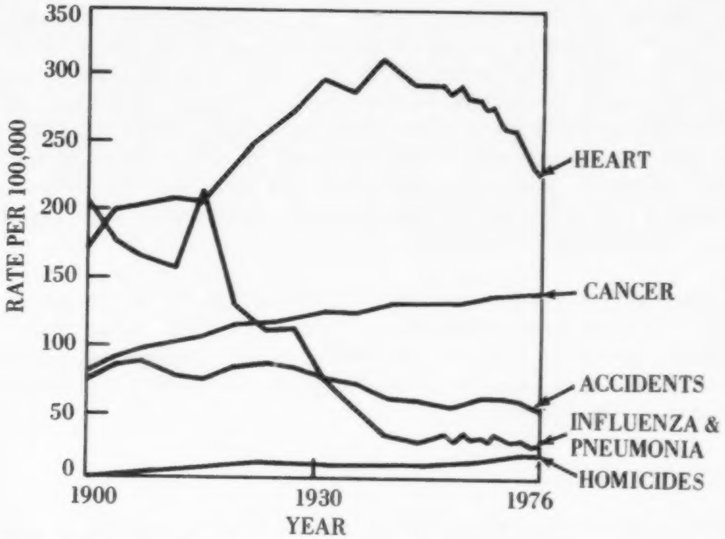
[50] Ames, B.N., "Identifying Environmental Chemicals Causing Mutations and Cancers," Science, Vol. 204, 1979, p. 587.

The outlook in this area is the most difficult to characterize; toxic effects on reproductive functions may be the most important at species survival level. A limited assessment can be made for chemicals that are known to have, or are highly suspected of having, toxic effects on reproductive systems. For example, the possible cancellation of most uses of the herbicide 2,4,5-T should result in less exposure to the highly teratogenic chlorinated dioxin, 2,3,7,8-TCDD, which is a contaminant of this herbicide. The possible reduction in TCDD exposures may, however, be negated by the projected increases in production of the wood preservative pentachlorophenol. Although evidence does not exist for the presence of 2,3,7,8-TCDD in pentachlorophenol, other chlorinated dioxins do exist as contaminants and could possess similar toxic characteristics. In addition, phasing out lead in gasoline may hold benefits in terms of impacts on developing young. However, pressures to increase gasoline availability may reverse this trend. Increased coal burning in this country may result in increased ambient levels of mercury, an element found in coal; possible conversion of ambient mercury to methylmercury may eventually result in fetal exposures.

These assessments are obviously limited both in scope and predictability. A true environmental outlook in this area must await a more complete understanding of the effects of chemicals on the reproductive system and the adequate testing of thousands of chemicals for their reproductive effects.

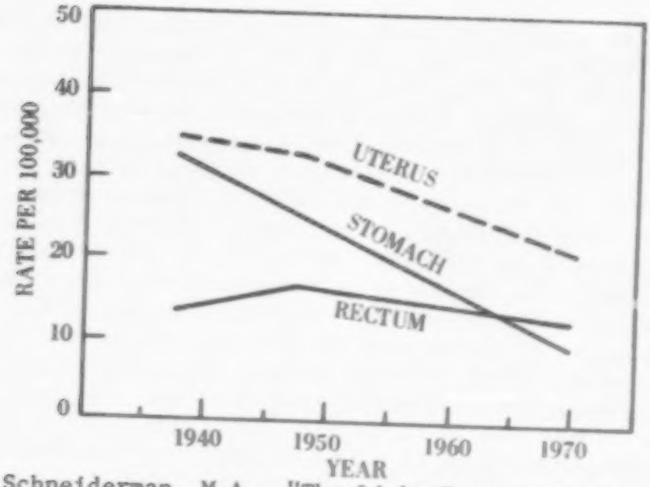
11.7.4 Carcinogenicity

Mortality trends in the United States are shown in Figure 11-5, with death rates corrected for shifts in age, race, and sex characteristics of the population. Deaths from infectious diseases such as influenza and pneumonia have fallen from first to fourth place and deaths due to heart disease are declining steeply. On the other hand, cancer mortality has shown a slow but constant growth; cancer is now the second most likely cause of death in the United States. Among various types of cancer, however, mortality rates are climbing or declining at rates different from this aggregated rate for all cancer mortalities (Figures 11-6 and 11-7). Mortality rates from cancer of the uterus, stomach, and rectum are declining--perhaps reflecting improved diagostic procedures--whereas lung cancer mortality has quadrupled between the years 1940 and 1970. Incidence rates of other cancers have been increasing slowly but steadily by about 1 percent per year since 1940.



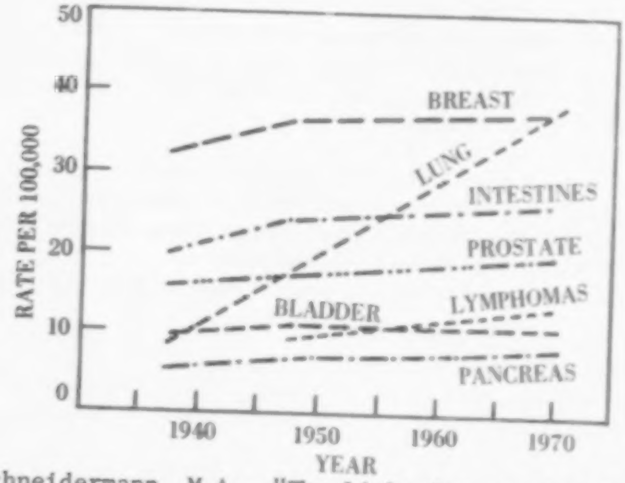
Source: Schneiderman, M.A., "The Links Between Environment and Health," in National Conference on the Environment and Health Care Costs, U.S. Government Printing Office, Washington, D.C., August 15, 1978.

FIGURE 11-5
MORTALITY RATES IN THE UNITED STATES



Source: Schneiderman, M.A., "The Links Between Environment and Health," in National Conference on the Environment and Health Care Costs, U.S. Government Printing Office, Washington, D.C., August 15, 1978.

FIGURE 11-6
MORTALITY RATES FROM CANCER IN THE UNITED STATES



Source: Schneidermann, M.A., "The Links Between Environment and Health," National Conference on the Environment and Health Care Costs, U.S. Government Printing Office, Washington, D.C., August 15, 1978.

FIGURE 11-7
MORTALITY RATES FROM CANCER IN THE UNITED STATES

Epidemiological studies of such incidence rates support the hypothesis that environmental factors are a major cause of cancer.[51] For instance, the rate of cancer incidence has been shown to correspond to population density, a factor termed urbanization, and smoking. Similarily, strong correlations have been shown between industrial (especially chemical) activity of a geographical region and cancer incidence, as evident in the 1975 NCI Cancer Atlas Study.[52] Moreover, the occurrence of different incidence rates for certain types of cancers in different parts of the world has, in particular, brought forth the importance of environmental factors. For example, very low rates of breast and colon cancers and a high rate of stomach cancer occur in Japan, and in the United States the reverse is true. However, when Japanese people immigrate to the United States, within a generation or two they show the same characteristics of high colon and breast cancer rates and low stomach cancer occurrence as other Americans. Such findings support the hypothesis that environmental factors are the major contributing source for cancer occurrence. Environmental constituents implicated in human cancers include cigarette smoke tar, ultraviolet light, X-rays, asbestos, and a list of chemical carcinogens that has steadily increased.[53]

Chemical carcinogens have been identified through examination of their effects on workers in the occupational environment; many more have been found through animal experimentation. Of these carcinogens, many--such as benzene, a highly suspected human leukemogen; ethylene dichloride, a mammalian carcinogen; and vinyl chloride, a known human carcinogen--are known to be released into the environment, benzene in large quantities.[54]

Although large amounts of chemical carcinogens are released, their final environmental concentrations and the expected resulting exposures experienced by the general population usually are low compared to those found in occupational situations or used in animal experimentation. Whether or not the general population will suffer adverse effects from such low-level exposures is a question for debate. Chronic toxicity studies, in which a few hundred animals are exposed to relevant, but very low doses of a chemical, may not yield statistically significant information. However, dose-response information from humans on lung cancer incidence and smoking[55] and from human exposures to radiation provides no support for the existence of an exposure "threshold"--a point below which any lower dose does not produce the adverse effect. Several arguments suggest that thresholds, or completely safe exposure levels for the general population, are not likely to be the case for carcinogens;[56] and until data prove otherwise, it is prudent to assume a linear proportional increase in risk with an increase in exposure.

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[51] Hiatt, H.H., J.D. Watson, and J.A. Winsten, eds., Origins of Human Cancer, Cold Spring Harbor Laboratory, Cold Spring Harbor, New York, 1977.

[52] U.S. Department of Health, Education, and Welfare, National Cancer Institute, Atlas of Cancer Mortality for U.S. Counties: 1950-1969, DHEW Publication No. NIH 75-780, 1975.

[53] Ames, B.N., "Identifying Environmental Chemicals Causing Mutations and Cancers," Science, Vol. 204, 1979, p. 587.

[54] Stephenson, M.E., "An Approach to the Identification of Organic Compounds Hazardous to the Environment and Human Health," Ecotoxicology and Environmental Safety, Vol. 1, 1977, pp. 39-48.

Epidemiological studies of cancer incidence indicate existence of a latent period between exposure to a carcinogen and the onset of most types of human cancer. Men started smoking cigarettes in large numbers around 1900, but the resulting incidence of lung cancer did not appear until 20 to 25 years later (Figure 11-8). Women did not start smoking in appreciable numbers until about the mid 1940s, and the rapid climb of lung cancer incidence in women has been only relatively recent. The latent period has also been seen with most types of cancer caused by the atomic bomb and cancer in factory workers exposed to certain chemicals.

As a result of cancer onset latency, the latest available cancer incidence rates reflect exposures that occurred soon after World War II. The dramatic increase in production and use of chemicals in the United States since the 1950s means increased exposure as well. But any significant increases in human cancer from these sources may not become obvious until the 1980s, owing to the 20- to 30-year lag. Similarly, it may be decades before we observe any beneficial results (in terms of decreased cancer incidence) from regulations recently adopted for the control of carcinogen exposures. According to David Rall, Director of the National Institute of Environmental Health Sciences,[57]

> ...as the average latency period for most occupational cancers ranges from 15 to 35 or more years, it is obvious that the bulk of industry-associated cancers that will appear over the next one to two decades will result from initial exposures that

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[55] Doll, R., "An Epidemiological Perspective of the Biology of Cancer," Cancer Research, Vol. 38, 1978, p. 3573.

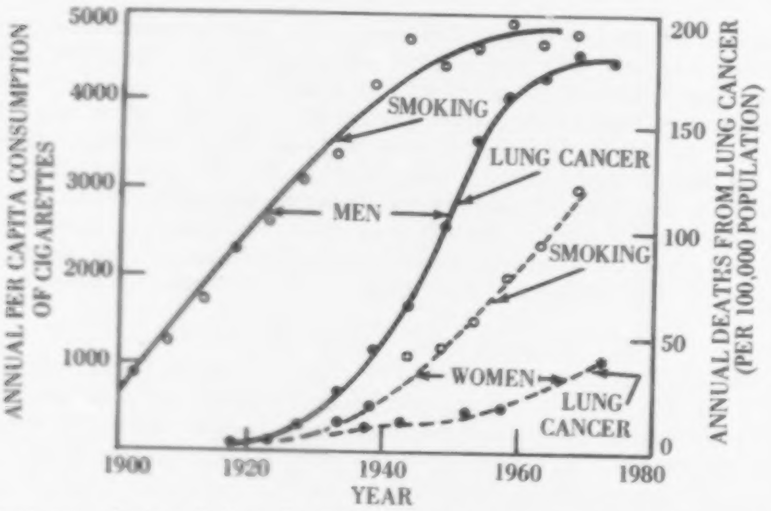
[56] Ames, B.N., "Identifying Environmental Chemicals Causing Mutations and Cancers," Science, Vol. 204, 1979, p. 587.

[57] Rall, D., "Occupational Cancer Risk," Science, Vol. 203, 1979, p. 224.

> occurred typically before 1960....Thus, recent reductions in exposure levels--often brought about by federal regulation and intervention--are not likely to markedly alter the incidence of tumors in these cohorts in the next one or two decades.

Moreover, the projected trends, as described in the preceding section, of rapidly increasing chemical production in general and of specific chemicals known to be carcinogenic (benzene, vinyl chloride, etc.) may reduce or completely negate any future benefits from regulation, in terms of cancer incidence over the long run.

In conclusion, the near-term environmental outlook holds a likely continuation of increasing cancer incidence, perhaps even a sudden jump in cancer occurrence, as a result of the highly increased chemical production activity that occurred in the years following World War II and the reduction in other life-threatening diseases. The long-term environmental outlook remains less clear; increased regulation and control of exposures to carcinogens may eventually have beneficial impacts on cancer incidence rates. However, such benefits may be overridden by the projected rapid increase in chemical production from now until at least the year 2000.



Source: Ames, B.N., "Identifying Environmental Chemicals Causing Mutations and Cancers," Science, Vol. 204, 1979, p. 587. Used with permission.

FIGURE 11-8
CIGARETTE CONSUMPTION AND LUNG CANCER MORTALITY IN THE UNITED STATES

CHAPTER 12
RADIATION

HIGHLIGHTS OF CHAPTER 12

Ionizing Radiation

- Ionizing radiation is known to cause cancer at high dose levels, but the potential health effects of low doses are the subject of scientific controversy. Extrapolations from high dose information have been used to infer that perhaps 3,500 cancer deaths per year (1 percent of U.S. cancer deaths) are attributable to background radiation.

- Medical diagnostic procedures are the largest artificial source of exposure to ionizing radiation for the general public. The annual per capita average dose is comparable to natural background. The outlook is for increased medical use of radiation procedures. It is not clear whether the trend toward elimination of unnecessary examinations and reduction in dose per examination will be sufficient to avoid an increase in the population dose. However, EPA and HEW have issued Federal guidance, which should help.

- Nuclear energy activities provide a very small part of the radiation exposure of the general population, in normal operations. Two problems of particular environmental concern are radioactive waste disposal and radon, and radon daughter emissions from waste tailings. There are about 70 nuclear power plants operating in the United States and 90 under construction. Beyond that, future trends are in doubt partly because of the safety questions raised by the accident at the Three Mile Island plant in 1979.

Nonionizing Radiation

- The recent proliferation of communications, broadcasting, radar, and other electronic devices has fostered concern for public and occupational exposure to nonionizing radiation.

- Radio waves and microwaves of frequencies between 30 MHz and 3 GHz are the major concerns.

- In the United States, less than 1 percent of the population is exposed to levels above 0.001 mW/cm^2. (The U.S. OSHA standard is 10 mW/cm^2; the standard for public exposure in the U.S.S.R. is 0.001 mW/cm^2.)

- The primary effects on the human body are heat-induced at high exposure levels (well above the OSHA standard). These include heat stress, burns, and eye cataracts.

- At very low exposure levels, there is some evidence for behavioral effects. However, existing data are insufficient to resolve the controversy over this point.

12.1 INTRODUCTION

12.1.1 Problem Definition

Growing concern by both the general public and the scientific community about ionizing and nonionizing radiation focuses on the potential for adverse effects on human health and the environment.

At present, the use of ionizing radiation in the healing arts is recognized as the largest artificial component of radiation dose to the U.S. population. In addition, other environmental sources such as the products and byproducts of the phosphate and coal industries may present significant sources of exposure in certain parts of the country.

The nuclear power debate, in addition to raising questions of weapons proliferation, has called public attention to two main ionizing radiation issues: reactor safety and the disposal of radioactive wastes.

Sources of ionizing radiation are present in the natural environment, the workplace, and the home. Exposures vary, depending on the source and type of radiation, but on the average, the larger doses are associated with natural background and medical exposures. Although other somatic and genetic effects can result from ionizing radiation, the primary concern is cancer.

Nonionizing radiation is an environmental problem that was largely ignored by the general public until the mid 1970s when it was announced that the U.S. Embassy in Moscow was being irradiated by microwaves. Around the same time, it was feared that SSTs might deplete the atmospheric ozone, thus exposing people to more solar ultraviolet radiation. Since then, nonionizing radiation has been increasingly studied, although not with the same urgency as that attached to nuclear questions.

Nonionizing radiation comes from diverse sources, such as communications equipment and microwave ovens. Based on results from animal studies, the principal effects of radiofrequency and microwave radiation are heat stress, burns, and cataracts of the eye. These are heat-induced at power levels higher than usually encountered in the general environment, but which could be encountered accidentally in occupational settings. Some scientists have reported behavioral effects at low levels of irradiation; however, others consider these findings questionable. Solar ultraviolet radiation, in contrast, is clearly associated with human skin cancer.

12.1.2 Organization of Chapter

Following this introductory section, ionizing and nonionizing radiation are discussed in separate sections, each of which includes a discussion of regulations, data, radiation sources, trends, and implications.

The various radiation sources are illustrated in Figure 12-1. The distinction between ionizing and nonionizing electromagnetic radiation is that at frequencies below that of ultraviolet light, the photons (units of electromagnetic radiation) have insufficient energy to remove an electron from an atom with which they may interact. Therefore, radiation at frequencies below about 10^{16} Hertz (Hz)[1] is nonionizing radiation. Radiation of higher frequency is ionizing radiation because it can remove an electron from and thus ionize the target atom.

Alpha and beta[2] radiation is composed of high-energy particles, which are actually helium nuclei and electrons, respectively, rather than photons of electromagnetic radiation. Since these particles can ionize an atom or molecule with which they interact, they are included as kinds of ionizing radiation.

12.2 IONIZING RADIATION

12.2.1 Introduction

Radioactive materials and X-ray machines produce energetic radiation. When absorbed by tissue, this radiation can produce damage by ionization.

In modern society, people are exposed to artificial sources of ionizing radiation at levels nearly equal to natural background, predominantly as a result of medical diagnostic activities. Industrial activities, including nuclear power, also contribute to this increased exposure. Certain workers, patients, and others receive exposures

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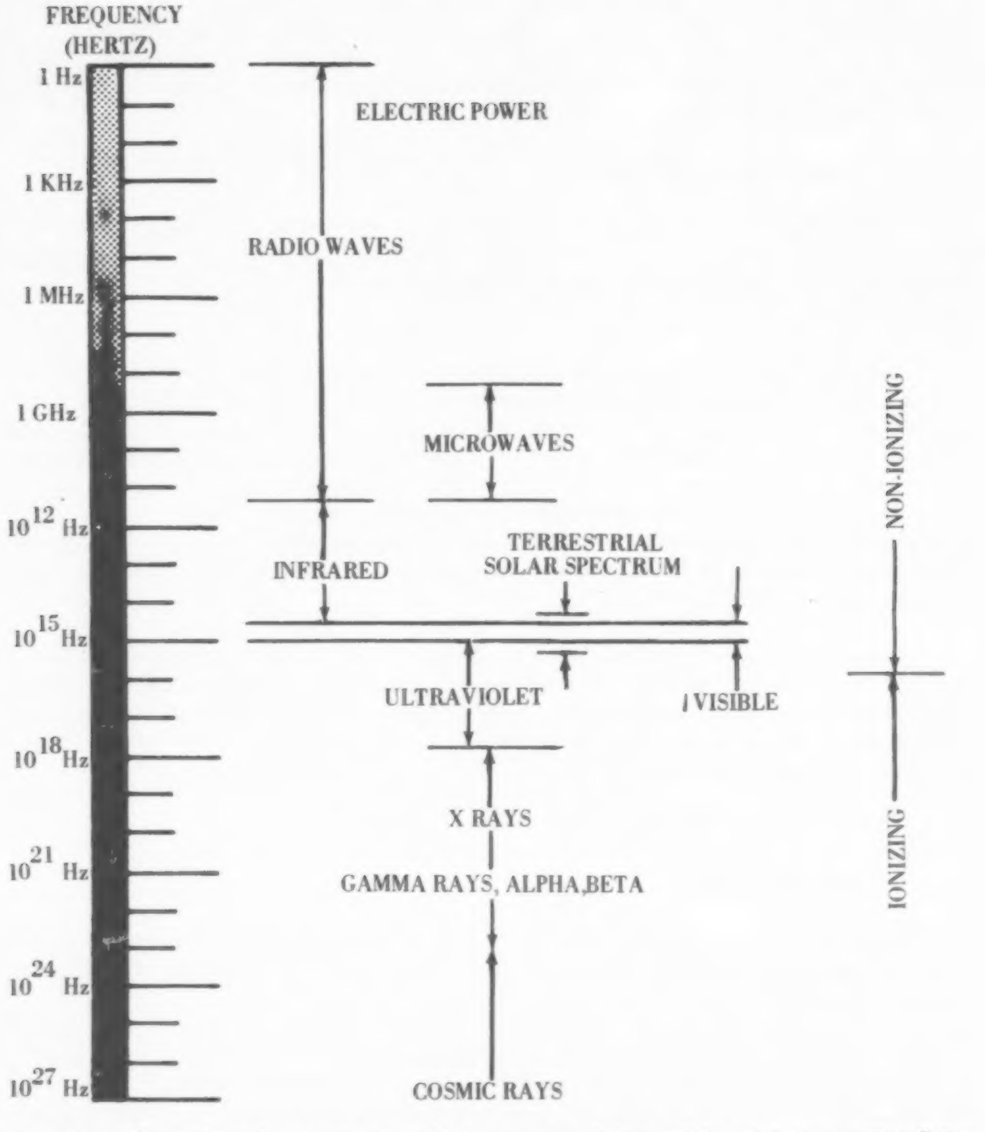
[1] One Hertz (Hz) is a unit of frequency equal to one cycle per second. One kiloHertz (KHz) equals 1,000 Hertz; 1 megaHertz (MHz) equals 1,000,000 Hertz; 1 gigaHertz (GHz) equals 1,000,000,000 Hertz.

[2] Beta particles may be either positively or negatively charged.


FREQUENCY (HERTZ)
1 Hz
1 KHz
1 MHz
1 GHz
10^{12} Hz
10^{15} Hz
10^{18} Hz
10^{21} Hz
10^{24} Hz
10^{27} Hz
ELECTRIC POWER
RADIO WAVES
MICROWAVES
INFRARED
TERRESTRIAL SOLAR SPECTRUM
ULTRAVIOLET
VISIBLE
X RAYS
GAMMA RAYS, ALPHA,BETA
COSMIC RAYS
NON-IONIZING
IONIZING

Note: Alpha and Beta radiation have energy comparable to gamma rays, but are particles not electromagnetic radiation.

Source: U.S. Department of Health, Education and Welfare, Human Health and the Environment: Some Research Needs, Report of the Second Task Force for Research Planning in Environmental Health Sciences, Washington, D.C., DHEW Pub. No. NIH 77-1277, 1977.

FIGURE 12-1
THE RADIATION SPECTRUM

considerably above the average, and this has become a source of public concern. Just how does the trend toward increasing use of radiation affect public health? Definitive answers are not yet available; the scientific issues are still under debate.

Alpha particles, beta particles, neutrons, gamma rays, and X-rays are the five kinds of radiation discussed here which can initiate the ionization process. Ultraviolet light, which in some cases has just enough energy to cause ionization, is discussed in Chapter 5 in connection with stratospheric ozone.

Ionizing radiation, whether produced naturally or artificially, has biological effects caused by ionization of molecules of living tissue. The primary concern is that incompletely or incorrectly repaired cell damage can produce delayed health effects, such as cancer, developmental abnormalities, or genetic damage.

The unit of ionizing radiation dose is the rem, a measure of the biological damage per unit mass caused by a given radiation dose.[3] The millirem (mrem), equal to 1/1,000 rem, also is frequently used. The radiation dose depends on the intensity of the radiation, and the length of exposure (see Table 12-1).

The effect of radiation depends on which organs or tissues are irradiated, as well as upon the dose. Dose rate and the type of radiation are also important. Whole-body radiation involves exposure of all organs, as is typical of external natural background radiation. However, radiation can be, and often is, limited to a part of the body, as in diagnostic and therapeutic X-rays.

12.2.2 Regulatory Background

Statutory authority for regulation of radiation comes from such diverse sources as the Atomic Energy Act of 1954 (PL 83-703); the

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[3] Strictly speaking, dose itself is measured in rads, where 1 rad of radiation deposits 100 ergs of energy per gram of tissue. The rem is a measure of biological effect, a dose equivalent obtained by multiplying the dose in rads by a quality factor which is dependent upon the kind of radiation and other factors. In qualitative terms, 1 rem (1,000 millirem) is roughly equal to the whole body exposure received by a person 1 meter away from a gamma ray source of 1 curie strength (such as 1 gram of radium 226) for 1 hour. A typical chest X-ray dose is 44 millirem. An acute fatal dose is about 600,000 millirem. The radiation exposure of a group of people is expressed in person-rem. This collective population dose is calculated by multiplying the number of people exposed times the average individual dose in rems.

TABLE 12-1
ANNUAL INDIVIDUAL IONIZING RADIATION DOSE
(U.S. POPULATION AVERAGE)

Source	Annual Exposure (mrem)
Natural Background[a]	
Cosmic radiation	28 (26-50)
Terrestrial radiation	52 (41-83)
(External = 26 mrem)	
(Internal = 26 mrem)	
Subtotal	80+ mrem/yr
Artificial Background[b]	
Medical diagnostic[c]	72
Radiopharmaceuticals	1
Occupational	0.8
Global fallout	4
Nuclear fuel cycle[d]	0.02
Miscellaneous	2
Subtotal	80 mrem/yr
Total	160 mrem/yr

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[a] National Council on Radiation Protection and Measurements, Natural Background Radiation in the United States, NCRP Report No. 45, Bethesda, Maryland, 1975. Internal is a computed average including cosmogenic and inhaled radionuclides.

[b] National Academy of Sciences, Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR), The Effects on Populations of Exposure to Low Levels of Ionizing Radiation, 1972, p. 12.

[c] Average abdominal dose to the whole population. A similar value has been obtained by William H. Ellett, Chief, Bioeffects Branch, Office of Radiation Programs, EPA who obtained an estimate of 70 mrem per year, using an age-weighted value based on Bureau of Radiological Health estimates of the dose to bone marrow and age at exposure.

[d] Keeny, S.M. et al., Nuclear Power Issues and Choices, Ballinger Publishing Co., Cambridge, Massachusetts, 1977, p. 163.

Energy Reorganization Act of 1974 (PL 93-438), which covers regulation of nuclear power and certain nuclear materials; and the Radiation Control for Health and Safety Act of 1968 (PL 90-602), which authorizes HEW to regulate radiation-emitting electronic products, including medical and dental equipment.

Table 12-2 lists the major responsibilities of various Federal agencies concerning radiation. Other nongovernmental advisory bodies, such as the National Council on Radiation Protection and Measurements and the International Commission on Radiation Protection, issue technical guidelines. Three particularly important agencies that help regulate radiation are EPA, the Nuclear Regulatory Commission, and the Bureau of Radiological Health of the Food and Drug Administration.

Under Executive Reorganization Plan No. 3 of 1970, several Federal radiation responsibilities were transferred to EPA. These included the former functions of the Federal Radiation Council (FRC), namely, advising the President on radiation matters and issuing radiation protection guidance to all Federal agencies; establishing generally applicable environmental radiation protection standards; and monitoring radiation levels in the environment.[4] EPA is also required to issue regulations to control the ocean disposal of radioactive wastes (see Chapter 9);[5] to establish standards for radioactive air pollutants;[6] and to set general environmental standards for disposal of uranium milling tailings.[7] Except under the Clean Air Act, EPA's jurisdiction is limited to areas outside the boundaries of facilities under the regulatory control of the Nuclear Regulatory Commission (NRC).

The Nuclear Regulatory Commission implements radiation protection standards by licensing construction and operation of nuclear power plants and fuel cycle facilities. NRC also regulates non-Federal use of source materials (uranium or thorium), byproduct materials (reactor-produced radioactive isotopes), and special nuclear material (plutonium and enriched uranium).

The Bureau of Radiological Health in the Food and Drug Administration is the lead agency for regulation of the manufacture and distribution of medical devices containing radioactive materials; they also set performance standards for X-ray machines and other electronic products that emit radiation. No Federal authority exists to regulate

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[4] 42 USC 2011.

[5] Marine Protection Research and Sanctuaries Act of 1972 (PL 92-532).

[6] Clean Air Act Amendments of 1977 (PL 95-95).

[7] Uranium Mill Tailings Radiation Control Act of 1978 (PL 95-604).

TABLE 12-2
FEDERAL AGENCIES WITH PRIMARY REGULATORY RESPONSIBILITY FOR RADIATION HEALTH AND SAFETY

Area of Responsibility	Agency[a]			
	EPA	HEW (FDA)	NRC	Other
General Environmental	X			
Nuclear Energy Industry	X		X	
Other Industries	X			
Federal Facilities & Workers	(operating agency, such as DOE)			
Workers (Private)			X	DOL (MSHA & OSHA)
Electronic Products and Medical Devices & Products[b]		X	X	
Consumer Products		X	X	CPSC
Food		X		
Transportation			X	DOT, USPS

[a] Full agency names: EPA, Environmental Protection Agency; HEW, Department of Health, Education & Welfare; FDA, Food & Drug Administration; NRC, Nuclear Regulatory Commission; DOE, Department of Energy; DOL, Department of Labor; MSHA, Mine Safety & Health Administration; OSHA, Occupational Safety & Health Administration; CPSC, Consumer Product Safety Commission; DOT, Department of Transportation; and USPS, United States Postal Service.

[b] No Federal authority exists to regulate medical use of radiation, and only the devices and products are regulated.

medical use of radiation by physicians, dentists, and x-ray technicians. EPA may issue recommendations for proper use and these recommendations are coordinated with HEW. An example of this is the 1978 report "Radiation Protection Guidance to Federal Agencies for Diagnostic X-rays." Once adopted by the President, these guidelines are enforceable in the Federal establishment.

12.2.3 Data Sources and Quality

The data used in projecting ionizing radiation trends have been gathered from most of the agencies mentioned above. In addition, the basic source for radiation effects information is the National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR). A useful summary has been prepared by the Interagency Task Force on the Health Effects of Ionizing Radiation,[8] chaired by HEW. EPA reports, such as Radiological Quality of the Environment,[9] have provided useful information on present and future radiation levels. The Department of Energy chaired an Interagency Review Group on Nuclear Waste Management which was the source of much of the information on nuclear power. The SEAS computer model used elsewhere in this report has limited capabilities in the radiation area, and was used in this chapter only as a source of population projections.

In general, information on future trends in medical uses of radiation is scarce. Projections are available for nuclear power, but their validity is questionable, since they were made before the accident at Three Mile Island. Other exposure pathways were not covered in any detail in this year's report, partly due to limitations of time and data.

12.2.4 Sources of Ionizing Radiation

Natural background (both cosmic and terrestrial) and medical and dental radiation are two major categories of sources of ionizing radiation. Two other categories of special interest are technologically enhanced natural radiation and the nuclear fuel cycle. Other sources are occupational activities, fallout from atmospheric nuclear weapons testing, radiopharmaceutical production and disposal, and consumer products.

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[8] U.S. Department of Health, Education, and Welfare, Report of the Interagency Task Force on the Health Effects of Ionizing Radiation, Washington, D.C., June 1979.

[9] U.S. Environmental Protection Agency, Office of Radiation Programs, Radiological Quality of the Environment, EPA 520/1-77-099, September, 1977.

Everyone is exposed to natural background levels of roughly 80 millirem per year (mrem/yr) of radiation due to cosmic rays, radioactive minerals, and internal radioisotopes. In addition, another 80 mrem is attributable to human activity, primarily medical uses of radiation. At present, the contribution from nuclear power generation is negligible: 0.023 mrem in 1975 (see Table 12-1).

Natural Background

Natural background is divided into cosmic radiation and terrestrial radiation. An average 18 percent of all exposure to radiation in the United States comes from cosmic rays emitted by sources in our galaxy, including the sun. Another 35 percent comes from terrestrial sources, both external and internal to the body. The most significant terrestrial radionuclides--potassium-40, uranium, thorium, and their daughters (especially radium and radon)--are naturally present in the soil and can act as external sources. These radionuclides can also enter the body through the consumption of food and water and through inhalation.

Medical and dental radiation treatments and techniques are the source of 45 percent of U.S. exposure. These include diagnostic radiology, especially radiographic procedures, clinical nuclear medicine, radiation therapy, dental X-rays, and radiopharmaceuticals.

In contrast to most radiation sources, medical procedures provide the exposed individual with specific benefits that need to be balanced against the risks of radiation exposure. These medical activities are the major artificial source of public exposure to radiation, and they are not always benign.

Technologically Enhanced Natural Radiation

Technologically enhanced natural radiation comes from natural radionuclides that have been redistributed by human activity, such as mining, excavation, well-drilling, and fertilizer production. It provides less than 1 percent of average U.S. exposure, but it can be important locally. One of the most important sources is uranium mill tailings piles, which contain radioactive nuclides such as radon, radium, and thorium. When these substances enter the water and air, they become sources of radiation exposure to miners and the local population. Before the problem was really understood, and before regulatory controls were established, mill tailings containing substantial radioactive concentrations were even used in Utah and Colorado as fill material on construction sites for homes and schools.

Abandoned radium processing sites in at least nine states have also been recently identified. This problem will require a large-scale clean-up effort for which Federal matching funds have been authorized by Congress.

Another example of this type of source is tailings from the mining of phosphate rock in Florida. EPA recently has directed attention to this problem. The production of elemental phosphorus and air emissions from coal-fired power plants can also be significant sources of radiation.

The Nuclear Fuel Cycle

The nuclear fuel cycle begins with mining and milling, progresses to conversion and enrichment of the uranium and fabrication of reactor fuel, and is expected to end with disposal of spent fuel or high level waste (see Figure 12-2). Nuclear fuel rods are used to generate power in nuclear power stations and research reactors.

Disposal of radioactive waste is a problem of great public concern today. Plans call for spent fuel from these reactors to be placed in geological storage, but such facilities are not yet available. Spent fuel rods are presently stored temporarily under water. Most of these are in containers at the reactor sites. There are similar plans for geological storage of high-level defense wastes.

The entire nuclear fuel cycle also generates large quantities of low-level radioactive waste,[10] such as transport containers, tools, gloves, and materials which are usually disposed of by shallow land burial or, occasionally, disposal at sea.[11] Potential exposure pathways to such wastes include contact with contaminated water or ground surface, inhalation, and ingestion.

Other Sources

Occupational radiation exposure contributes about 1/2 of 1 percent of U.S. population exposure. However, it may contribute a more significant fraction of exposure of individual workers in occupational

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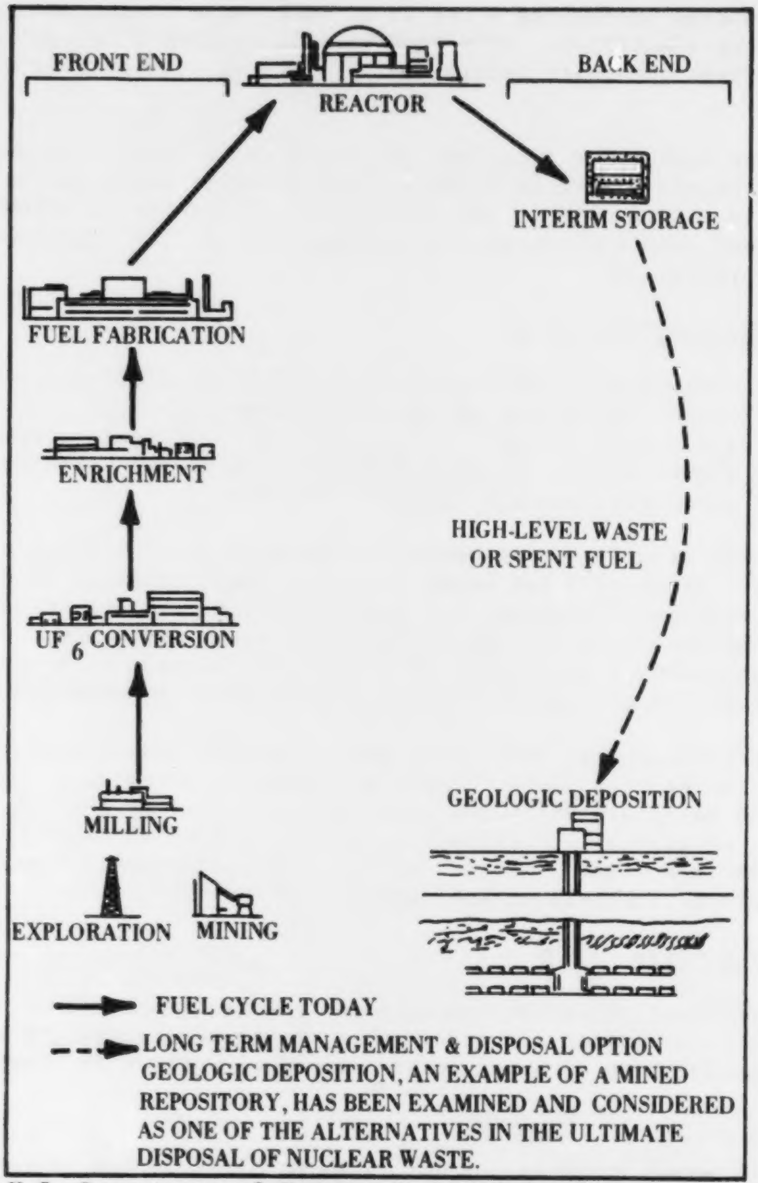
[10] Low level waste contains quantities of material so low in radioactivity that they require little shielding, as contrasted with high level wastes, including spent fuels, which are highly radioactive.

[11] The United States prohibits the disposal of "other than low level" radioactive wastes at sea. However, some other countries dump low-level radioactive wastes in the oceans. Refer to 10 CFR 20.302 and 36 FR 23138.


FRONT END
REACTOR
BACK END
INTERIM STORAGE
FUEL FABRICATION
ENRICHMENT
HIGH-LEVEL WASTE OR SPENT FUEL
UF$_6$ CONVERSION
MILLING
GEOLOGIC DEPOSITION
EXPLORATION
MINING
FUEL CYCLE TODAY
LONG TERM MANAGEMENT & DISPOSAL OPTION GEOLOGIC DEPOSITION, AN EXAMPLE OF A MINED REPOSITORY, HAS BEEN EXAMINED AND CONSIDERED AS ONE OF THE ALTERNATIVES IN THE ULTIMATE DISPOSAL OF NUCLEAR WASTE.

Source: U.S. Department of Energy, Energy Information Administration, Annual Report to Congress, Vol. II: Projections of Energy Supply and Demand and Their Impacts, DOE EIA-0036/2, Washington, D.C., 1977, p. 192.

FIGURE 12-2
THE NUCLEAR FUEL CYCLE

and industrial settings that involve radiography or use of radionuclides. The possibility of carcinogenesis due to exposure to low-level radiation has attracted much attention lately and is discussed below.

Fallout from nuclear weapons tests contributes about 2 or 3 percent of U.S. exposure. The radioactive strontium and cesium in this fallout are deposited worldwide.[12] Fallout radiation has declined since the cessation of most atmospheric nuclear testing in the mid 1960s, but fallout from past tests still contributes to internal and external population doses.[13]

Radiopharmaceutical production, use, and disposal contribute about 1/2 of 1 percent of U.S. population exposures. Radiopharmaceuticals, used in diagnosis and treatment of many diseases, expose patients and those that come in contact with them to both internal and external radiation. Both manufacturers of radiopharmaceuticals and users, including medical facilities, discharge small quantities of these materials to the environment.

Numerous consumer products contain or produce radiation, but at exceedingly low levels. A few examples are digital watches, glazes and glass, uranium as a color agent, ionization chamber smoke detectors, artificial teeth,[14] color TV, fertilizer, plasterboard, and cinder blocks.

Nuclear Accidents

Most environmental concerns discussed in this report are related to continuing releases and exposure to pollutants under normal conditions. However, nuclear energy facilities present another concern, that of a very large release in a single major accident. This leads to the question of nuclear reactor safety. It is still true, as the Ford-MITRE Study[15] concluded in 1977, that "...there have been no demonstrable adverse effects to public health" in 200 reactor years

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[12] Klement, A.W. Jr. et al., Estimates of Ionizing Radiation Doses in the United States, 1960-2000, ORP/CSD 72-1, August 1972, p. 14.

[13] U.S. Environmental Protection Agency, Radiological Quality of the Environment, EPA 520/1-77-099, September 1977, p. 114.

[14] Moghissi, A.A., Radioactivity in Consumer Products, U.S. Nuclear Regulatory Commission, NUREG/CP-0001, 1978, pp. 475-478. Uranium oxide is added to get the proper fluorescence. It causes a local dose to the mouth of the user of about 700 mrem per year.

[15] Keeny, S.M. et al., Nuclear Power Issues and Choices, Ballinger Publishing Co., Cambridge, Massachusetts, 1977, p. 163.

(now more than 470 reactor years). That record is excellent but still of limited value in assessing the likelihood of a low probability accident in the future.

Several events in 1979 have raised questions about reactor safety. In the Reactor Safety Study report, done in 1977 for the Nuclear Regulatory Commission by a group headed by M.I.T. professor Norman Rasmussen, it was concluded that the risk of death to any person from a reactor accident was comparable to the risk of being hit by a meteorite.[16] However, in January of 1979, after a careful external review, the NRC withdrew its endorsement of the Rasmussen report as an instrument for quantitative risk estimates.

In March 1979, serious core damage occurred at the Three Mile Island reactor in Harrisburg, Pennsylvania. Fortunately, the core was contained within the reactor vessel, and there was no major radiation release. Nuclear opponents describe this as a close call and say that we should stop nuclear power--we might not be so lucky next time. Nuclear supporters point out that, despite many flaws, both human and technical, the backup safety systems were adequate to prevent anyone from getting hurt.

The anticipated future health effects of radiation from that accident are minimal so far, although a full assessment must await completion of the cleanup. An interagency team from NRC, HEW, and EPA gathered data on the collective radiation doses received by the 2 million people residing within 50 miles of the reactor, and projected only one additional cancer death during the lifetime of the population, compared to 325,000 deaths during the expected lifetime of that population due to cancer from other causes.[17] However, the cleanup process is still going on, and that could lead to additional radiation exposure.

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[16] Rasmussen, N.C., The Reactor Safety Study Report; An Assessment of Accident Risks in the U.S. Commercial Power Plants, WASH-1400-NUREG 75/014, U.S. Nuclear Regulatory Commission, October 1975.

[17] Nuclear Regulatory Commission, U.S. Environmental Protection Agency, and U.S. Department of Health, Education, and Welfare, Ad Hoc Population Dose Assessment Group, Population Dose and Health Impacts of the Accident at the Three-Mile Island Nuclear Station: A Preliminary Assessment for the Period March 28 through April 7, 1979, May 10, 1979, p. 2.

These events are a reminder that, in projecting the environmental outlook, the possibility of a catastrophic accident with significant environmental consequences must be considered. In that context, an adequate analysis would have to consider natural disasters such as earthquakes and floods, as well as transportation accidents with hazardous chemicals.

12.2.5 Trends

The two artificial sources of ionizing radiation exposure that seem to be receiving the greatest attention are medical exposure and the nuclear fuel cycle. Technologically enhanced natural radiation from mining, construction, and increased coal combustion may produce greater population exposures than the nuclear fuel cycle, but trends information was not available for inclusion in this report.

Medical Exposure

Medical exposure to radiation differs from exposure to most pollutants and from exposure to radiation via other pathways in that the exposure itself is intended to serve a beneficial purpose. It is not just an unwanted side effect of another activity. However, the question remains whether the medical purpose in any given instance can be served with lower radiation exposure, or even without the use of radiation. Some reports suggest the over 50 percent of medical radiological procedures involving genetically significant doses may be unnecessary.[18]

Data in Table 12-3 show a projected increase of 23 percent in population dose from diagnostic radiology between 1975 and 2000. This projection is based on population projections from the SEAS High Growth Scenario and the 1970 estimated mean gonad dose rate of 72 mrem/person.[19]

The scenario assumes no change in medical practice. More accurate figures would take into account the efforts by the medical community to reduce exposure from any given procedure and to eliminate unnecessary procedures. In addition, the figures would also consider the opposing tendency toward increased exposures, as radiological diagnostic procedures are chosen more often and as some new procedures require increased exposures. These factors are discussed briefly below.

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[18] National Academy of Sciences, Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR), The Effects on Population of Exposure to Low Levels of Ionizing Radiation, 1972, p. 13.

[19] Klement, A.W. Jr. et al., Estimates of Ionizing Radiation Doses in the United States, 1960-2000, U.S. Environmental Protection Agency, ORP.CSD 72-1, Montgomery, Alabama, 1972, p.88.

TABLE 12-3
TRENDS IN RADIATION DOSE TO U.S. POPULATION FROM DIAGNOSTIC RADIOLOGY

Year	Population (millions)	Genetically Significant Dose (million person-rem)
1960	183	11.1
1964	192	11.7
1970	205	14.7
1975	213	15.3
1985	234	16.8
2000	262	18.8

SOURCE: Calculated from SEAS High Growth Scenario population projections with dose rates taken from Klement, A.W. Jr. et al., Estimates of Ionizing Radiation Doses In the United States, 1960-2000, U.S. Environmental Protection Agency, ORP.CSD 72-1, Montgomery, Alabama, 1972, p. 88.

An increasing trend in the annual per capita dose for the U.S. population between 1964 and 1970 is shown in Table 12-4. The major cause for the rise is attributable to the female population, although the reason for this sex difference was not identified. Between 1964 and 1970, the per capita dose to women from radiography increased by 24 percent and that from fluoroscopy increased by 11 percent, while for men the per capita dose from radiography hardly changed and that from fluoroscopy declined by 12 percent.

There has been a marked increase in the number of diagnostic X-ray examinations performed in the United States in the period 1966-1976; an increase estimated to be 1 to 4 percent annually. In the period from 1964-1970, there was a 20 percent increase in the number of people receiving X-ray procedures, while the population only increased by 7 percent. There was also a 22 percent increase in the number of X-ray examinations per person, and a 10 percent increase in the average number of films per examination. An EPA review in 1976 concluded that these trends have probably continued since 1970, especially insofar as increased film usage is concerned.[20]

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[20] Radiation Protection Guidance for Diagnostic X-Ray, Federal Guidance Report No. 9, EPA 520/4-76-99, October 1976, pp. 3-4.

TABLE 12-4
TRENDS IN DOSE FROM DIAGNOSTIC RADIOLOGY 1964 and 1970
(SIMULATED OVARIAN DOSE - MALE; OVARIAN - FEMALE)

Year	Annual per Capita Dose for the Exposed Population (mrem)			Size of Exposed Population (thousands)	Fraction of Whole U.S. Population	Annual per Capita Dose for the Whole U.S. Population (mrem)
	Male	Female	Both			
1964						
Radiography	150	126	138	66,086	0.354	49
Fluoroscopy	273	318	296	7,779	0.042	a
1970						
Radiography	148	156	153	75,400	0.377	58
Fluoroscopy	239	394	328	8,600	0.043	a

[a] Annual per capita dose as a result of fluoroscopy was not calculated because of the small size of the population exposed.

Source: Klement, A.W. Jr. et al., Estimates of Ionizing Radiation Doses in the United States, 1960-2000, U.S Environmental Protection Agency, ORP.CSD 72-1, Montgomery, Alabama, 1972, p. 88.

The trend in radiation exposure per examination is mixed, as shown in Table 12-5. The radiation dose from an average dental X-ray examination has declined by about 30 percent, as has that from fluoroscopic chest examination. However, the average dose for a radiographic chest examination has remained constant, and that for an abdominal examination has actually increased by over 25 percent. Since abdominal examinations contributed 77 percent of the total active mean bone marrow dose to adults from diagnostic radiology, while fluoroscopic examinations and dental examinations contributed only 20 and 3 percent respectively, the increases outweigh the decreases so far as total population exposure is concerned.[21] However, for those many individuals who do not have extensive abdominal examinations involving X-rays, the average dose has declined.

TABLE 12-5
TRENDS IN DOSE PER EXAMINATION
(MILLIRADS MEAN ACTIVE BONE MARROW DOSE)[a]

Examination	1964	1970
Chest-Photofluoroscopic	65	44
Chest-Radiographic	10	10
Upper Abdomen	408	535
Lower Abdomen	624	875
Dental	13.2	9.4

[a] Millirads are approximately equal to millirems.

SOURCE: U.S. Environmental Protection Agency, Radiological Quality of the Environment, U.S. Government Printing Office, Washington, D.C., 1977, pp. 213-214.

In at least two well-known instances, the use of radiological diagnostic procedures has been greatly reduced. General X-ray screening for tuberculosis has been replaced by a skin test, with X-ray screening used only when the skin test is positive. Similarly, as mentioned above, use of X-ray mammographic screening for breast cancer has been restricted to high-risk groups such as older women and those with a family history of breast cancer.

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[21] U.S. Environmental Protection Agency, Radiological Quality of the Environment, U.S. Government Printing Office, Washington, D.C., 1977, p. 210.

The trend in medical radiological exposures is mixed. One hopeful sign is the recent guidelines for cancer-related health checkups issued by the American Cancer Society.[22] For example, the Society has recommended eliminating chest X-rays for the detection of lung cancer and, except for high risk groups, has revised the schedule for mammograms.

The Nuclear Fuel Cycle

There are about 70 nuclear power plants licensed for operation, representing 50 gigawatts[23] of electric generating capacity (GWe) in the United States. Another 90 or so additional plants, representing about 100 GWe, have construction permits and are in various stages of construction.[24] Because of the time needed for planning and construction, it is unlikely that this number could be substantially increased over the next decade. Thus, unless there is a complete moratorium (even on plants already started), the United States expects to have about 150 GWe of nuclear power by the late 1980s.

Projections of nuclear capacity to 2000, however, are very uncertain. Changing conditions have required dramatic changes in these projections. In Figure 12-3, nuclear power growth estimates made in the past few years are compared. In 1972, the Atomic Energy Commission forecast 1,200 GWe of nuclear power by the end of this century. More recent forecasts have been successively lower. For example, a 1977 Energy Research and Development Administration (ERDA) forecast was 380 GWe. The most recent (1979) DOE forecasts are about 260 GWe,[25] but they must be considered uncertain because of the possible effects of the Three Mile Island incident in delaying further nuclear construction.[26]

Radioactive Waste

A major environmental concern in nuclear energy use is radioactive waste disposal. Radioactive waste is hazardous and may be very

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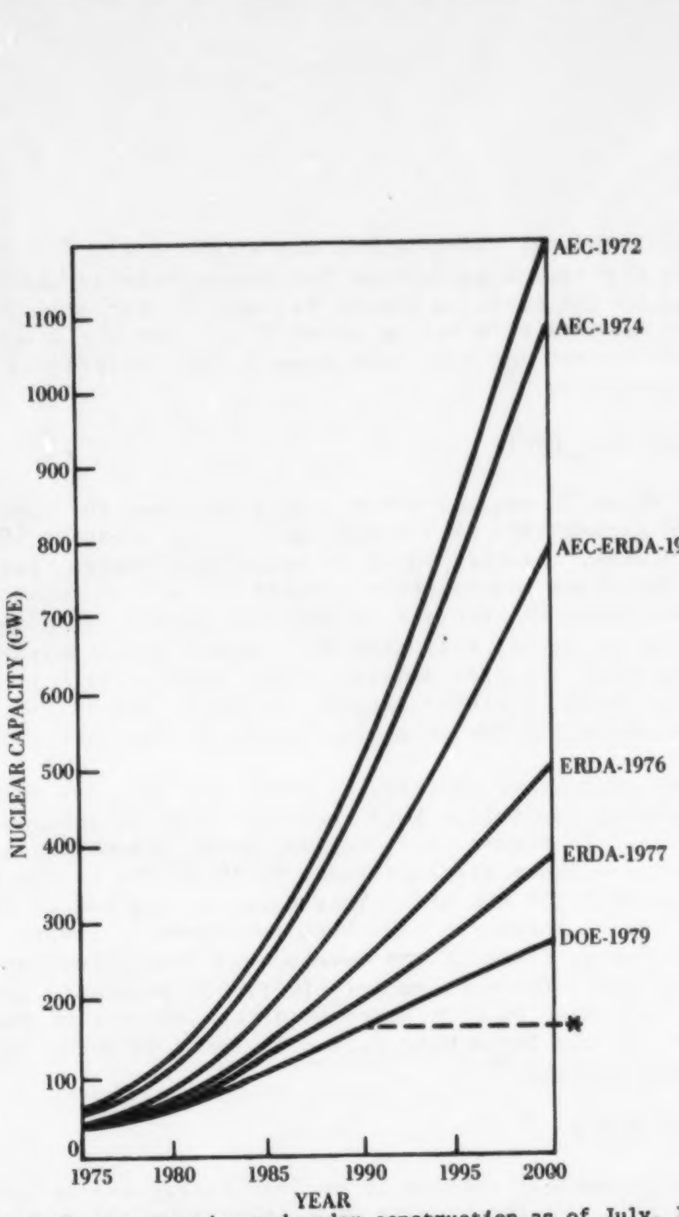
[22] American Cancer Society, Memorandum LE-40, New York City, March 14, 1980.

[23] One gigawatt (GWe) = 1 thousand megawatts or 1 million kilowatts of electric generating capacity. One gigawatt also corresponds roughly to the capacity of one modern nuclear power plant.

[24] U.S. Department of Energy, Energy Information Administration, Monthly Energy Review, March 1980 p. 69.

[25] U.S. Department of Energy, Energy Information Administration, Annual Report to the Congress, Vol. 3, DOE/EIA-0173/3, 1978, p. 222.

[26] U.S. Department of Energy, National Energy Plan II, May 1979, p. 39, forecasts 15.2 to 16.5 quads, depending on oil prices. This translates to 243-264 GWe.



*Number of plants operating and under construction as of July, 1979.

Note: It requires about one quad of thermal energy to generate 16 GWE of electrical power for a year, in a nuclear plant, assuming 60 percent capacity. U.S. Department of Energy, National Energy Plan II, May 1979, p. 40.

Source: Adapted from Testimony of James R. Schlesinger, Assistant to the President, before the Subcommittee on Fossil and Nuclear Energy Research, Development and Demonstration of the Committee on Science and Technology, United States House of Representatives, June 7, 1977, Table 1.

FIGURE 12-3
NUCLEAR POWER GROWTH ESTIMATES

long-lived. It must be carefully isolated from the biosphere for long periods of time--some wastes for thousands of years. In this respect it is similar to persistent toxic substances discussed in Chapter 11. If it were to leach into the ground water or be dispersed in the air, the general public could be exposed to large amounts of radiation with corresponding adverse health effects. But it is difficult to assess either the likelihood or the probable impact of such events. Trends in radioactive waste disposal will be governed by trends in nuclear power production and by future choices of waste disposal practices.

The major classes of nuclear wastes are as follows:[27]

- High-level wastes (HLW) are either spent fuel (intact reactor fuel assemblies that are discarded after having served their useful life) or the wastes generated if spent fuel were reprocessed. Disposal of these wastes in geologic repositories is being considered. However, the scientific feasibility of the mined concept is not yet established.

- Transuranic (TRU) wastes contain radioactive elements heavier than plutonium, and result from spent fuel reprocessing, decommissioning, and the fabrication of plutonium to produce nuclear weapons. These wastes are to be disposed in a similar manner to high-level waste.

- Low-level wastes (LLW) contain less than 10 nanocuries[28] of transuranics per gram. They require little or no shielding and contain low but potentially hazardous quantities of other radionuclides. Low-level wastes are generated in almost all activities involving radioactive materials and are presently disposed of by shallow land burial.

- Uranium mine and mill tailings, the residues from uranium mining and milling operations, contain low concentrations of naturally occurring radioactive materials. The tailings are generated in very large volumes and are now stored at the site of mining and milling operations. Currently there are 22 inactive mill tailings sites in the United States.

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[27] U.S. Department of Energy, Interagency Review Group on Nuclear Waste Management, Report to the President, TID-294-42/UC-70, March 1979, p. 42.

[28] One nanocurie equals 1 billionth of a curie, while 1 curie is that amount of radioactive material that produces 3.7×10^{10} decays per second, for example 1 gram of radium.

The Interagency Review Group on Radioactive Waste (IRG) stated in their March 1979 report that for high-level waste, actual disposal rather than long-term interim storage is the proper approach in order to avoid leaving a problem for future generations. However, selecting methods and sites is subject to considerable uncertainty. In addition to technical problems, there may be political problems in selecting the states where waste sites would be located. In fact the political problems may be the more difficult. Thus, more than 30 years into our nuclear age, we have no permanent solution to the waste disposal problem. This prospect has led several leading officials and legislators to suggest that a cutoff date be set for generating radioactive waste until a disposal facility is in place. The IRG adopted a neutral position on that point.[29]

Some nuclear specialists have suggested reprocessing spent fuel to recover any remaining fissionable uranium and plutonium, and then disposing of the remaining high-level waste. However, current U.S. policy is to dispose of the spent fuel rods without reprocessing. President Carter made this decision in 1977 to avoid the added risk of weapons proliferation or nuclear terrorism that could arise if separated plutonium (weapons-grade material) were obtainable (at whatever point) in the nuclear fuel cycle. Environmentally, disposal of spent fuel and disposal of separated high-level waste present similar problems, problems that are in some ways similar to those encountered with persistent toxic chemical wastes.

Although low-level waste and uranium mill tailings are less radioactive than high-level waste, their greater volume and less stringent disposal requirements make them a cause for concern. The leakage of radon gas from old mill tailings material has been identified as a serious problem, since this material was not regulated in the past. However, there is now authority for regulation of uranium mill tailings, and it is anticipated that this problem will be corrected.

Despite the emphasis in this discussion on high-level waste, it should not be concluded that the problems of low-level waste are trivial. In fact, low-level waste is generated at a rate approaching 10 million cubic feet per year. This includes substantial amounts from biomedical uses, which will be generated even in the absence of nuclear power. This problem attained some prominence in October

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[29] U.S. Department of Energy, Interagency Review Group on Nuclear Waste Management, Report to the President, TID-294-42/UC-70, March 1979, p. 7.

1979, when two of the remaining three U.S. low-level disposal sites, in Nevada and Washington, were closed temporarily by state order. The commercial waste is primarily in the form of spent fuel, while the defense waste is in the form of reprocessed high-level waste and separated TRU waste. However, the amount of radioactive waste that has been generated by the commercial nuclear power industry is now comparable, in terms of its radioactivity, to that generated by defense activities. Furthermore, the radioactive waste generation rate from defense activities is relatively small and constant, while that from commercial nuclear power is larger and growing.

Projections of the future quantities of radioactive waste generated in 2000 are shown in Table 12-6 for two nuclear scenarios, Case 1 (148 GWe) corresponding to plants presently operating or with construction permits and Case 2 (380 GWe) corresponding roughly to DOE's 1977 growth projections. In either case, the quantities of radioactive waste will be significant.

In summary, high-level waste, consisting of both spent fuel rods and reprocessing waste, is considered the crux of the nuclear fuel cycle problem. At present, there are 9 million cubic feet of defense high-level wastes stored temporarily in the United States; another 2 thousand tons of spent reactor fuel needs storage. With the continued operation of nuclear power plants, which discharge about 30 tons of spent fuel yearly, this figure may rise to 100 thousand tons by the end of the century.

Table 12-7 gives two projections of the increase in nuclear fuel cycle facilities corresponding to the scenarios in Table 12-6. After the Three Mile Island accident, it seems likely that these should be taken as upper limits on the number of facilities to be expected.

Global Fallout

In the past, great concern was expressed over global fallout, but following cessation of atmospheric testing of nuclear weapons by the United States and the Soviet Union in 1962, the problem has decreased. There have been only a few, relatively small tests by other countries (China, India, and France) since then, and their effect has been correspondingly small. Table 12-8 illustrates the decline in dose rates; however, it also shows a continuing annual dose of about 4 mrem/person resulting from long-lived contamination left behind from previous tests. Global fallout is third only to natural background and medical-dental radiation as a source of the radiation dose to the U.S. population (see Table 12-9).

TABLE 12-6
RADIOACTIVE WASTE GENERATION

Type	Existing Waste	2000: Case 1 148 GWe		2000: Case 2 380 GWe	
		Amount Generated	Acres Required for Disposal	Amount Generated	Acres Required for Disposal
High-Level Waste (million ft^3)	9.4	a	54	a	491
Transuranic Waste (million ft^3)	15	7	186	116	3,177
Spent Fuel[b] (thousand tons)	2.3	71.1	1400	97.8	2,900
Low-Level Waste (million ft^3)	67	121	438	450	1,636
Uranium Mill Tailings (million tons)	140	1,900	-	5,200	-

[a] As planned, without reprocessing, there will be no additional separated commercial HLW. Defense projections are classified but small.

[b] Fuel that is reprocessed 150 days after removal from a reactor has about 4 million curies of radioactivity and 20 kW of heat per metric ton of fuel processed. This leads to 4,000 liters of high-level waste, which is then concentrated to 600 liters per metric ton of fuel, or 21.2 ft^3 per metric ton. On this basis, the spent fuel inventory would be equivalent to about 48,000 ft^3.

Sources: U.S. Department of Energy, Interagency Review Group on Nuclear Waste Management, Report to the President, March 1979, pp. 11, 12, D-3,-7,-8,-10,-15,-17,-18, and -21. Also, English, T.D. et al., An Analysis of the Technical Status of High-Level Radioactive Waste and Spent Fuel Management Systems, JPL Pub. #77-69, California Energy Resources Conservation and Development Commission, p. 5-1.

TABLE 12-7
NOMINAL "LIFETIME" REQUIREMENTS FOR NUCLEAR WASTE MANAGEMENT AND DISPOSAL

Requirement	Case 1[a]	Case 2[a]
Geologic Repositories:		
For defense high-level wastes	1	1
For defense transuranic wastes	1	2
For commercial high-level waste[b]	2	5
Potential Away-From-Reactor Spent Fuel Storage Facilities:		
If repository opens in 1988	3	3
If repository opens in 2000	12	14
Low-Level Waste Disposal Sites: (acres-required)		
Commercial low-level wastes	300	950
Defense low-level wastes	140	700
Uranium Mine and Mill Tailings:		
Billions of tons	1.9	5.2
Number of sites	40	40
Decontamination and Decommissioning Activities:		
Number of facilities decontaminated and decommissioned (commercial facilities only)	148	380

(continued)

TABLE 12-7 CONCLUDED

Requirement	Case 1[a]	Case 2[a]
Transportation:		
Low-level waste volume[c]	120	450
Number of trips with high-level wastes[d]	1400	3200
Transuranic waste volume[c]	6.8	116

[a] Defined in Appendix B: Case 1 -- 148 GWe by 2000; Case 2 -- 380 GWe by 2000.

[b] The requirement for repository space is not sensitive to the decision to dispose of spent fuel or to reprocess the spent fuel and recycle the uranium and plutonium.

[c] Millions of cubic feet, cumulative through the year 2000.

[d] The number of trips does not include interim storage of spent fuel in an AFR storage facility. Depending on the date of a repository opening, these numbers could be 50 percent higher.

Source: U.S. Department of Energy, Interagency Review Group on Nuclear Waste Management, Report to the President, TID-29442/UC-70, March 1979, p. 12.

TABLE 12-8
TOTAL ANNUAL WHOLE BODY DOSES FROM GLOBAL FALLOUT

U.S. Population (millions)		Per Capita Dose (mrem)	Man-rem for U.S. Population Year (millions)
1963	190	13	2.47
1965	194	6.9	1.33
1969	204	4.0	0.82
1985	234[a]	4.5[b]	1.05
1990	245[a]	4.6	1.10
2000	262[a]	4.9	1.28

[a] SEAS High Growth Scenario
[b] Interpolated

Source: Klement, A.W. Jr. et al., Estimates of Ionizing Radiation Doses in the United States, 1960-2000, U.S. Environmental Protection Agency, ORP.CSD 72-1, Montgomery, Alabama, 1972, p. 22.

12.2.6 Effects of Ionizing Radiation

To present an effective analysis of the biological effects of ionizing radiation on the population, several factors must be specified. These include type of radiation, duration of exposure, dose (low or high[30]), dose rate, exposed group (workers, or sensitive groups such as children or pregnant women), and exposure route (internal or external). This discussion of biological effects is divided into four categories: human somatic (direct bodily health effects), human genetic, human growth and development, and general environmental effects.

Table 12-9 gives estimates of the collective radiation dose to the U.S. population and repeats the average individual radiation doses from Table 12-1.

Human Health Effects

The consequences of whole body acute exposure to high doses of radiation are known. A dose of 450 to 600 rem causes failure of the blood-forming tissue and results in a 50 percent chance of death within a few weeks, in the absence of treatment. Doses of less than 100 rem produce few acute somatic symptoms, although lymphocyte depression can be detected at doses of 25 to 50 rem. At lower levels, a cause-effect relationship cannot be directly traced in individual cases. However, at doses below 5 rem, statistical increases in fatalities have been observed among uranium miners.[31] The linear no-threshold hypothesis is customarily used to extrapolate to very low dose rates, leading to an assumed risk of 180 deaths per million person-rem and about an equal number of serious non-fatal healths effects as discussed below. In comparison, the risk of genetic mutation over the first five generations is estimated to be about 400 mutations per million person-rem.

Acute Somatic Effects. The acute clinical symptoms of exposure to radiation appear only at very large doses--25,000 millirems and above. Acute fatal doses are in the range of 300,000 millirems and above. Actual exposures that have produced acute symptoms have been rare, except as a result of atomic (i.e., nuclear) weapon use, and in some cases, cancer treatment.

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[30] The term low-level radiation can be ambiguous. In defining low-dose radiation, radiologists use tens of rem or less, while radiation protection specialists use tens to hundreds of millirem.

[31] Ham, J.M., Report of the Royal Commission on the Health and Safety of Workers in Mines, Ministry of the Attorney General, Province of Ontario, Toronto, 1976.

TABLE 12-9
RADIATION DOSE TO U.S. POPULATION

U.S. General Population Collective Dose Estimates - 1978	Millions of Person-rems per Year	Per Capita Average (millirem/yr)
Source:		
Natural background	20	100
Technologically enhanced	1	5
Medical and dental	18	90
Nuclear weapons fallout	1.3	6.5
Nuclear weapons development, testing, and production	0.0002	
Nuclear energy	0.06	
Consumer products	0.006	
U.S. Occupational Exposures Estimates - 1975		
Source:		
Healing arts	0.06	
Manufacturing and industrial	0.05	
Nuclear energy	0.05	
Research	0.01	
Naval reactors	0.01	
Nuclear weapons development and production	0.001	
Other occupations	0.05	

Note: These figures differ somewhat from those given in Table 12-1 but they are the same order of magnitude. It is hoped that the National Academy of Sciences BEIR-3 report will provide a definitive assessment of radiation doses when that report is released.

Source: U.S. Department of Health, Education, and Welfare, Report of the Interagency Task Force on the Health Effects of Ionizing Radiation, June 1979, p. 15.

Late Somatic Effects. The late somatic effects of ionizing radiation include leukemia and other forms of cancer that do not appear immediately but may take years to develop. For high doses other effects are important but they are not discussed here. Results of animal studies and scattered human data from atomic bomb survivors and occupational and therapeutic situations indicate a possible relationship between low doses and long-term health effects.[32] However, the magnitude of the effect is the subject of scientific controversy.

Data on both medical and occupational exposures show excessive occurrence of cancer in people subjected to radiation exposures greater than 50 rem. Increased cancer rates have been observed among radiologists and radium dial painters, and there is evidence of such an increase among nuclear workers.[33]

We do not know the health effects of low-level radiation from direct clinical evidence, but the 1972 BEIR Report[34] estimates roughly 180 cancer deaths per million person-rem exposure. There is supporting evidence from animal studies, but its application to humans is a matter of interpretation. The BEIR Committee estimated that background radiation is responsible for 1,700 to 9,000 cancer deaths per year in the U.S. population with a best estimate of 3,500 (i.e., 1 percent of all cancer deaths).

The linear, no-threshold hypothesis is illustrated in Figures 12-4 and 12-5. This hypothesis extrapolates from the high-level radiation data to low doses by fitting a straight line, with a positive slope at zero dose, as in curve (1). It assumes that however small the dose, there is some probability of cancer.

However, this extrapolation ignores the possibility of cell repair mechanisms[35] which might reduce the risk due to exposure at low levels, in effect producing a threshold. There is some evidence for such a repair mechanism with certain types of radiation, such as

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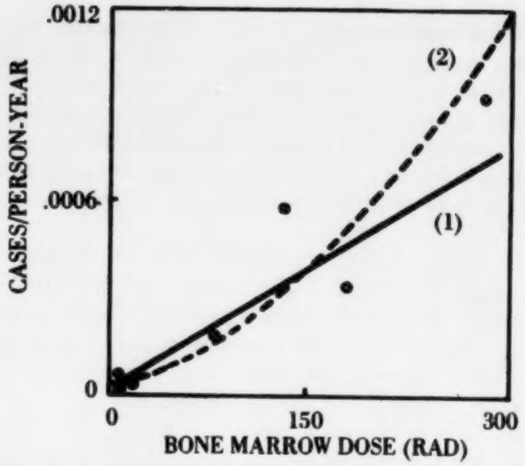
[32] Libassi, F.G., Biological Effects of Ionizing Radiation, Report of the Work Group on Science of the Interagency Task Force on Ionizing Radiation, June 1979, p. 7. See also Figures 12-4 and 12-5 in this report.

[33] Ibid, pp. 17-19.

[34] National Academy of Sciences, Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR), The Effects on Populations of Exposure to Low Levels of Ionizing Radiation, 1972, p. 170. Using the relative risk model.

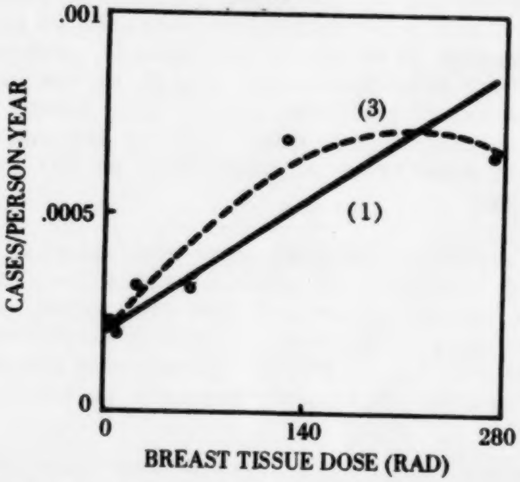
[35] Ibid, pp. 64-65.



Note: Curve (1) is a linear fit; Curve (2) is added as an example of a threshold response.

Source: Adapted from U.S. Department of Health, Education and Welfare, Report of the Work Group on Science, Interagency Task Force on the Health Effects of Ionizing Radiation, June 1979, p. 72.

FIGURE 12-4
LEUKEMIA INCIDENCE IN A-BOMB SURVIVORS, NAGASAKI
1950-1971



Note: Curve (1) is a linear fit; Curve (3) is added as an example of a saturation effect.

Source: Adapted from U.S. Department of Health, Education and Welfare, Report of the Work Group on Science, Interagency Task Force on the Health Effects of Ionizing Radiation, June 1979, p. 74.

FIGURE 12-5
BREAST CANCER INCIDENCE IN A-BOMB SURVIVORS
HIROSHIMA AND NAGASAKI
1950-1969

gamma rays. In such a situation the linear hypothesis leads to an over-estimation of the damage. A possible example of a threshold is seen in curve (2) of Figure 12-4 on leukemia incidence. Because of large statistical uncertainties in the data, it is not possible to conclude which curve, the linear or the threshold curve, is the more correct. However, the existence of a threshold at low levels cannot be excluded as a possibility for some types of effects.

On the other hand, the high-level data may be biased by a saturation effect due to cell-killing. If a cell is killed, it will not become cancerous, so high doses may produce fewer cancers than would otherwise be expected. Such an effect would mean that the risk due to low-level exposure is higher than that estimated from a linear fit to the data. A possible example of saturation due to cell-killing is shown by curve (3) in Figure 12-5 on breast cancer.[36] The data appear more consistent with a saturation effect at about 140 rad, above which there would be no further increase in cancer incidence (curve 3), than they do with a simple linear hypothesis (curve 1), but again the statistical uncertainties are too great to allow a definitive conclusion. Thus, there is continuing debate within the scientific community on how the actual risk compares with the linear no-threshold hypothesis.

Genetic Effects. The genetic effects of ionizing radiation are gene mutations and chromosome aberrations. Genetic effects simply imply transmission to later generations, in contrast to somatic effects, which are observed directly in the exposed generation. Thus, genetic effects are associated with damage to the gonadal cells of the organism, while somatic effects result from damage to other cells. Genetic effects can include many types of abnormalities which can appear in the first generation of offspring, or may be postponed for several generations.

Animal evidence supports the hypothesis that genetic effects occur at both high and low doses of ionizing radiation, but there is no direct evidence in humans. Extrapolation from animal data has been used to estimate the genetic risk to be 200 mutations or chromosomal aberrations per year for 10 million person-rem annual exposure.[37] This would imply 4,000 effects per year in the U.S.

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[36] Land, C.E., "Estimate of Risk From Low-Dose Exposures to Ionizing Radiation," Journal of the National Cancer Institute, in press, cited in U.S. Department of Health, Education, and Welfare, Interagency Task Force on the Health Effects of Ionizing Radiation: Report of the Work Group on Science, 1979, p. 74.

[37] National Academy of Sciences, Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR), The Effects on Populations of Exposure to Low Levels of Ionizing Radiation, 1972, pp. 52-54.

population due to radiation background. However, there is some recent evidence that the genetic risk is less than previously thought.[38] The total spontaneous mutation rate for many genes (available from human data) ranges from 0.5×10^{-6} to 0.5×10^{-5} per gene per generation (or 40,000 effects total per year in the United States). Since we know that ionizing radiation can cause genetic mutations, the question remains, Is the risk of the associated increase in genetic mutation rate acceptable to society, when compared with the alternatives? We need additional information about radiation-induced mutation in humans and the role of mutations in maintaining disease incidence within a given human population.

Growth and Developmental Effects. Exposure to high levels of ionizing radiation as a fetus or juvenile may have three major effects on human growth and development: growth impairment, microcephaly (reduced head circumference), and mental retardation. Acute effects of ionizing radiation upon the human fetus are the destruction or alteration of developing cells. These damaged developing cells may prohibit or delay the correct development of organs or entire organ systems. Radionuclides from the external environment may concentrate within an organ, thus retarding body growth. A strong association exists between high, acute exposure (greater than 50 rem) and abnormal development, as exhibited in data from Japan, the Marshall Islands, and medical radiotherapy records. With chronic low doses of radiation, the results of animal studies disagree on whether there is an association with harmful developmental effects.[39] And, normal background exposures are several orders of magnitude below those used in these animal studies, so once again the analysis requires significant extrapolation, with all the uncertainty that implies.

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[38] Crow, J.F., University of Wisconsin, in a paper ("Can We Assess Genetic Risks?") presented to the 6th International Congress of Radiation Research (Tokyo, May 1979) stated that, on the basis of data from animal studies since BEIR-II, the genetic hazard of radiation appears much less than previously thought. The mutant strains were dying out after a few generations, rather than persisting, as assumed.

[39] National Academy of Sciences, Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR), The Effects on Populations of Exposure to Low Levels of Ionizing Radiation, 1972, pp. 78-81.

12.3 NONIONIZING RADIATION

12.3.1 Introduction

Microwaves, radio waves, and electromagnetic fields at power line frequencies, as well as other forms of nonionizing radiation, are widely present in our environment. Since World War II, technological advances have made many new applications of nonionizing radiation possible, so that it has become an integral part of our society. The public has become increasingly concerned about its effects, and asks many questions. Unfortunately, not enough is known yet to give clear answers to these questions.

Reports of microwave signals beamed at the U.S. Embassy in Moscow between 1953 and 1976 alarmed the public as well as the people working within the Embassy. However, a 2-year study, completed in 1978, conducted by Professor Abraham Lilienfeld of Johns Hopkins University found no apparent ill effects attributable to the radiation.[40]

Over half of the 112 reports, identified by FDA for the General Accounting Office[41] as being particularly relevant to setting microwave radiation standards, identify biological effects in animals or humans when exposed to radiation levels at or below present U.S. guidelines. These reports indicate that some biological systems respond to radiation levels previously considered too low to produce observable responses (1-10 mW/cm^2). However, neither the extent to which these effects actually compromise living systems nor the conditions necessary to produce such effects have been well defined.[42] In addition, care must be taken in scaling animal data to humans, because absorption rates in tissue are perhaps 5 times lower at 80 MHz (human resonance) than at 2 GHz (mouse resonance).

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[40] Lilienfeld, A.M., Evaluation of the Health Status of Foreign Service and Other Employees From Selected European Posts, NTIS: PB-288163, U.S. Department of State, July 31, 1978. Also, Microwave Irradiation of the U.S. Embassy in Moscow: A Review of its History and Studies to Determine Whether or Not Related Health Defects Were Experienced by Employees Assigned in the Period 1953-1977, prepared at the request of Hon. Howard W. Cannon, Chairman, Committee on Commerce, Science, and Transportation, U.S. Senate, April 1979, 96th Congress, 1st Session, U.S. Government Printing Office, Washington, D.C., 1979.

[41] U.S. General Accounting Office, More Protection from Microwave Radiation Hazards Needed, Report by the Comptroller General of the United States, HRD-79-7, November 30, 1978, p. 30.

[42] The Technical Review of the Biological Effects of Non-Ionizing Radiation, prepared for the Office of Science and Technology Policy by an ad hoc Working Group, May 15, 1978, p. 5.

There is increasing interest in the effects of high voltage transmission lines. A Johns Hopkins University Hospital study of electrical linemen who were regularly exposed to high electric fields from such lines showed no significant bodily changes.[43] However, some studies of workers in the U.S.S.R. at extra high voltage substations found that effects on the nervous system and cardiovascular systems of the workers were related to exposure to high voltage electric fields.[44] U.S. scientists do not agree on whether or not electric fields associated with transmission lines produce adverse biological effects.[45]

Government agencies, principally EPA, DOD, and HEW, are currently conducting research on the effects of electromagnetic radiation over a wide range of frequencies. A summary of these programs has been recently published.[46] Information for each frequency range is inadequate, and all require further research so that statistically valid conclusions can be reached about the relation between exposure and effects of nonionizing radiation.

12.3.2 Regulatory Background

The three primary Federal agencies responsible for the regulation of nonionizing radiation are EPA, HEW, and the Department of Labor, as shown in Figure 12-6.

Reorganization Plan No. 3 of 1970, which created EPA, also gave the Agency the responsibility to establish generally applicable environmental standards for nonionizing as well as ionizing radiation. This reorganization also transferred to the EPA Administrator

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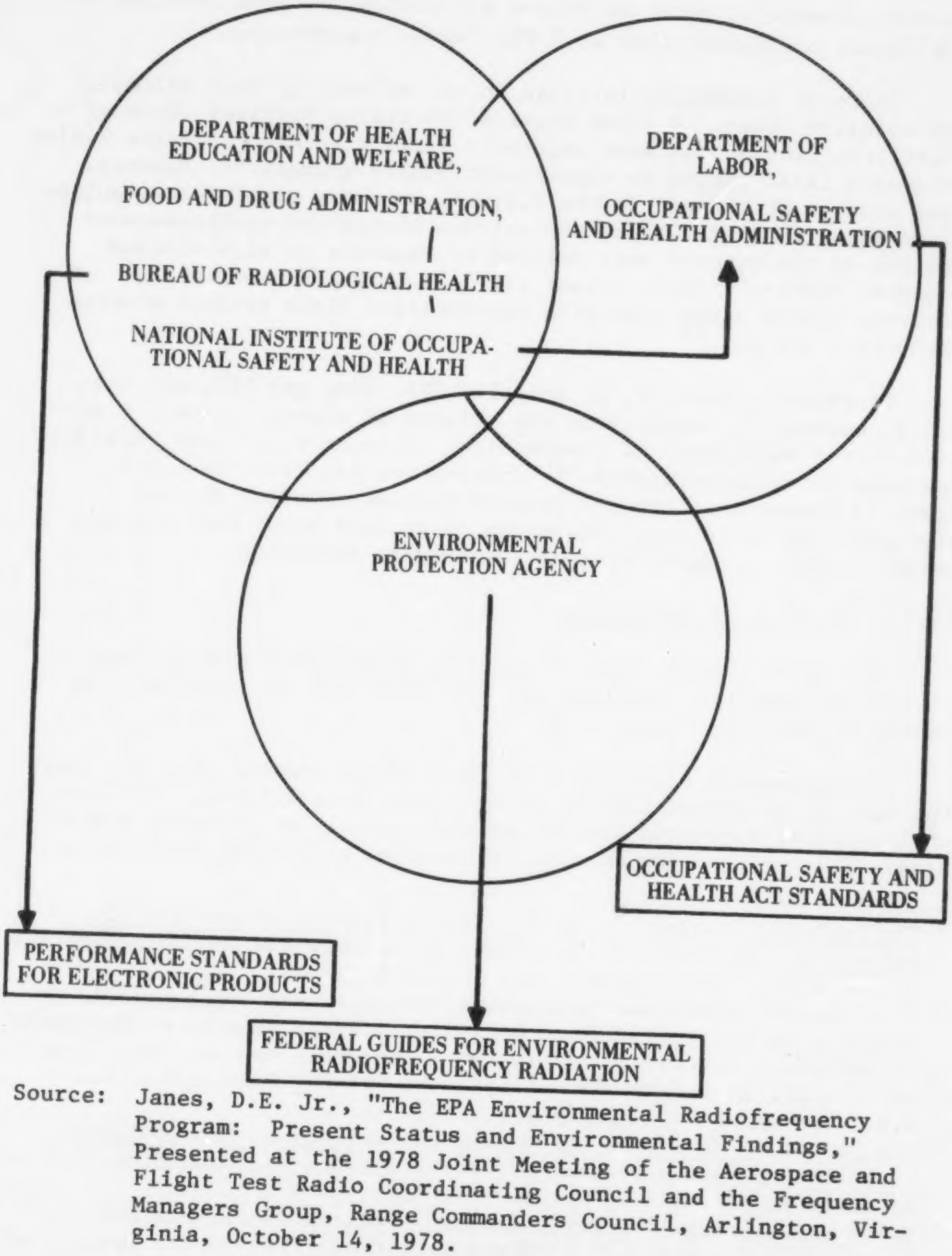
[43] The Technical Review of the Biological Effects of Non-Ionizing Radiation, prepared for the Office of Science and Technology Policy by an ad hoc Working Group, May 15, 1978, p. 43.

[44] U.S. Senate, Committee on Commerce, Science, and Transportation, Hearings on Radiation Health and Safety, First Session on Oversight of Radiation Health and Safety, 95th Congress, 1st Session, June 16, 17, 27, 28 and 29, 1977, Serial No. 95-49, Washington, D.C., U.S. Government Printing Office, 1977.

[45] The Technical Review of the Biological Effects of Non-Ionizing Radiation, prepared for the Office of Science and Technology Policy by an ad hoc Working Group, May 15, 1978, p. 43.

[46] U.S. Department of Commerce, National Telecommunications and Information Administration, Fifth Report on "Program for Control of Electromagnetic Pollution of the Environment: The Assessment of Biological Hazards of Nonionizing Electromagnetic Radiation," Washington, D.C., NTIA Report 79-19, March 1979.


DEPARTMENT OF HEALTH EDUCATION AND WELFARE,
FOOD AND DRUG ADMINISTRATION,
BUREAU OF RADIOLOGICAL HEALTH
NATIONAL INSTITUTE OF OCCUPATIONAL SAFETY AND HEALTH
DEPARTMENT OF LABOR,
OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION
ENVIRONMENTAL PROTECTION AGENCY
OCCUPATIONAL SAFETY AND HEALTH ACT STANDARDS
PERFORMANCE STANDARDS FOR ELECTRONIC PRODUCTS
FEDERAL GUIDES FOR ENVIRONMENTAL RADIOFREQUENCY RADIATION

Source: Janes, D.E. Jr., "The EPA Environmental Radiofrequency Program: Present Status and Environmental Findings," Presented at the 1978 Joint Meeting of the Aerospace and Flight Test Radio Coordinating Council and the Frequency Managers Group, Range Commanders Council, Arlington, Virginia, October 14, 1978.

FIGURE 12-6
AGENCIES RESPONSIBLE FOR NONIONIZING RADIATION

authority from the Federal Radiation Council to "...advise the President with respect to radiation matters, directly or indirectly affecting health, including guidance for all Federal agencies in the formulation of radiation standards and in the establishment and execution of programs of cooperation with States."[47] EPA is currently conducting research to determine possible health effects associated with microwaves, various broadcast frequencies, and power transmission line frequencies. Environmental measurements, evaluation, and the development of guidelines are carried out by EPA's Office of Radiation Programs, in the Office of Air, Noise, and Radiation.

The Department of Health, Education, and Welfare acquired its authority under the Radiation Control for Health and Safety Act of 1968 (PL 90-602). This authority is exercised by the Bureau of Radiological Health (BRH) of the Food and Drug Administration. BRH operates an electronic product radiation control program and develops performance standards.

The Occupational Safety and Health Act of 1970 (PL 91-596) gives the Department of Labor authority over occupational safety. This authority is exercised by the Occupational Health and Safety Administration (OSHA), with research support from the National Institute of Occupational Safety and Health (NIOSH).

In addition, the newly formed National Telecommunications and Information Administration (NTIA),[48] the successor to the Office of Telecommunication Policy (OTP), is assigned the responsibility for formulating national telecommunication policy. The Electromagnetic Radiation Management Advisory Council (ERMAC) advises NTIA on possible effects associated with the use of the electromagnetic spectrum. The Interdepartmental Radio Advisory Committee (IRAC) assists NTIA in developing policies and criteria for the use of the spectrum.

Federal standard setting activities for nonionizing radiation are in flux. In 1966, based on the results of experiments designed to assess the thermal effects of nonionizing radiation, the American National Standards Institute (ANSI) recommended a voluntary guideline of 10 mW/cm^2. OSHA endorsed the ANSI standard but the courts ruled this standard as advisory only. The Department of Defense adopted the ANSI standard; otherwise, at present, no legally enforceable occupational or environmental exposure standard exists. The BRH microwave oven standard became effective in October 1971 and applies to all microwave oven manufacturers. Accordingly, microwave ovens may not emit more than 1 mW/cm^2 at the time of production and 5 mW/cm^2 thereafter in the life of the product, measured at a distance of 5 cm from the oven.[49]

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[47] 2 USC 2021(h).

[48] National Telecommunication and Information Administration, Executive Order 12046, March 27, 1978, Federal Register, Vol. 43, pp. 13349-13357, March 29, 1978.

Several additional standards for nonionizing radiation are pending. The Bureau of Radiological Health has issued a proposed standard for microwave diathermy equipment. NIOSH is developing a criteria document with recommendations for occupational exposure to microwaves and other radio frequency sources. EPA is developing guidance for controlling environmental levels of radiofrequency radiation.[50] Congress has shown interest in this area and has held numerous hearings covering topics from microwave ovens to exposure of helicopter pilots to radio beams during flight training.

Recent research conducted by EPA's Experimental Biology Division of the Health Effects Research Laboratory at Research Triangle Park has found that at relatively low levels, chronic exposure to radio frequency radiation has induced morphological changes in brain tissue as well as immunological and behavioral changes, and blood chemistry effects in laboratory animals.[51] These results suggest that at certain frequencies the 10 mW/cm^2 standard fails to provide an adequate margin of safety. As a result, ANSI has proposed to lower the standard to 1 mW/cm^2 in the frequency range for human resonance (30-300 MHz).

12.3.3 Data Sources and Organization of Discussion

The Bureau of Radiological Health and EPA's Office of Radiation Programs and Office of Research and Development are the primary sources for nonionizing radiation data used in this report. Information on trends was obtained from the Electronics Industries Association.

12.3.4 Sources of Nonionizing Radiation

The three major sources of nonionizing radiation discussed here are microwaves, radio waves, and high voltage transmission lines. Other sources are ultraviolet, visible, and infrared light.

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[49] 21 CFR 1030.10.

[50] Start Action Notice, April 30, 1979.

[51] U.S. Environmental Protection Agency, Office of Research and Development, Research Outlook 1980, EPA 600/9 80-006, Washington D.C., February 1980, pp. 144-146.

Microwave radiation is radiofrequency radiation with frequency between 300 MHz and 300 GHz, which overlays the upper end of the frequency range of radio waves. Microwave radiation is emitted from microwave ovens, medical and dental diathermy apparatus, alarm systems, radar, communications relay systems, and industrial heating and drying devices.

Ordinary radio waves have frequencies from 10 KHz to 300 MHz and are emitted from TV and radio broadcast stations, radionavigational systems, amateur and industrial RF equipment, emergency medical radio, and long-range communications systems. The FM and VHF frequencies in the 30 MHz to 300 MHz band are of particular concern in regard to human health effects.

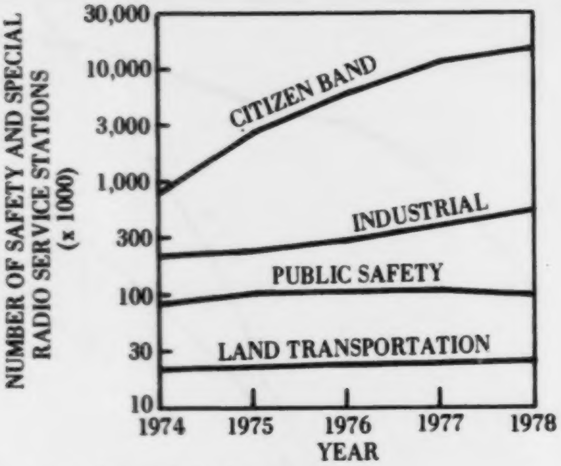
High voltage transmission lines for electric power operate at low frequencies (60Hz) but at voltages as high as 765 kilovolts. This in turn produces ground-level electric fields as high as 9 kilovolts per meter. Extremely low frequency (ELF) communication antennas produce radiation of similar frequency (70 Hz) but with much lower intensity.

Infrared (IR) light radiation has frequencies from 3×10^{11} to 3×10^{14} Hz and is emitted from any surface heated to a higher temperature than an adjacent surface. A transfer of heat energy occurs whenever radiant energy emitted by one body is absorbed by another.

Visible light radiation is emitted from the sun as well as from artificial light sources, arc-welding processes, and incandescent bodies. Lasers (Light Amplification by Stimulated Emission of Radiation) emit extremely high-intensity, coherent-light radiation of a single wavelength (or narrow band).

Ultraviolet (UV) light radiation is emitted from the sun, fluorescent lamps, and from industrial devices such as electric welding arcs and germicidal lamps. Human exposure can also result from lamps used in other occupational activities such as blueprinting, laundry marking, illuminating instrument dials, detecting crime, photo engraving, and sterilizing food, water, and air.

The greatest environmental concern centers on radiation from a frequency of 30 MHz to 300 MHz because this is the range of highest



Note: This is a logarithmic graph.

Source: Electronic Industries Association, Electronic Market Data Book: 1979, Washington, D.C., 1979, p. 43. Used with permission.

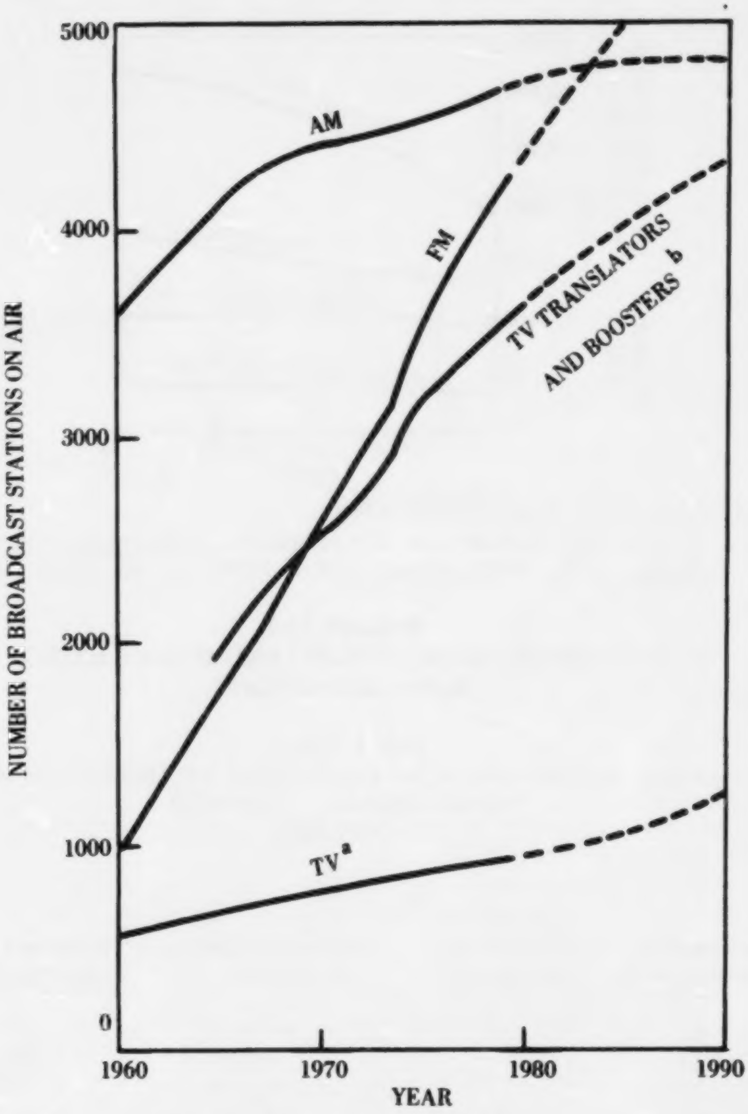
FIGURE 12-7
HISTORICAL INCREASES IN LAND MOBILE RADIO SERVICE STATIONS

TABLE 12-10
ANNUAL FACTORY SALES OF ELECTRONICS BY INDUSTRY GROUP
UNITED STATES: 1939-1988
($ MILLION)

Year	Government Products[a]	Industrial Electronic Component	Communications Equipment	Consumer Electronics	Total
1939	$ 37	-	-	186	186
1950	655		$ 1,005	1,500	2,505
1960	6,124		8,104	1,774	9,878
1970	11,295	$ 7,841	10,080	3,683	21,604
1978	16,300	24,462	19,787	9,303	53,552
1979	17,300	-	-	-	-
1983	20,800	-	-	-	-
1988	25,100	-	-	-	-

[a] Government is included in communications equipment and industrial electronic component, but is broken out seperately for convenience.

Source: Adapted from Electronic Industries Association, Electronic Market Data Book: 1979, Washington, D.C., 1979. Used with permission.



[a] Major high power TV broadcast stations.

[b] TV translators and boosters are low power broadcast stations which pick up transmission from the major TV broadcast stations and redirect the transmission to a given location.

Note: The data have been extrapolated for the years beyond 1978.

Source: Electronic Industries Association, Electronic Market Data Book: 1979, Washington, D.C., 1979, p. 50. Used with permission.

FIGURE 12-8
PROJECTED INCREASES IN BROADCAST SERVICES

a new product, microwave ovens, climbed from 50,000 units in 1971 to 1.6 million in 1976.[53] Sales of lasers reached $600 million in 1978 and continue to grow at a rate of about 15 percent per year. The number of major TV transmitters, while still rising, may be reaching saturation at about 1,000 units. This is 50 percent higher than its 1960 value, indicating an average annual growth rate below 2.5 percent.

The growth in these sources represents a significant economic investment. During 1978, sales of communications and electronic products totaled about $50 billion, more than doubling since 1971. Of this total, about 50 percent went into the civilian communication and industrial market, 30 percent into the government market, and 18 percent into the consumer-product market.[54]

The number of sources of nonionizing radiation is expected to increase. The number of microwave and radiofrequency sources is estimated to increase by 15 percent annually (see Figure 12-8). If these trends continue, it is projected that over 4,000 TV and 5,000 FM radio transmitters will be on the air by 1985, compared to 2,500 of each in 1970. This represents an increase of 5 percent per year. On the other hand, the number of AM radio transmitters appears to be reaching saturation at about 4,700, about 4 percent above the 1970 figure. And, as noted above, the number of major TV transmitters appears to be stabilizing at about 1,000; the rest are low power stations.

The Department of Defense is the largest user of nonionizing electromagnetic radiation devices. The U.S. Army alone has nearly 350,000 transmitting devices. Many are low powered, but some are very high powered, and these are not uniformly deployed. Figure 12-9 shows the location of 29 high-powered Army transmitters, of which over half are in New Mexico and Florida.[55] These systems are used for satellite communications and air defense.

One rather esoteric source of particular interest in projecting the future is the proposed solar power satellite, which would be a solar collector in orbit around the earth. Collected energy would be sent to earth by microwave beam. The environmental effects of such a system are still being evaluated.

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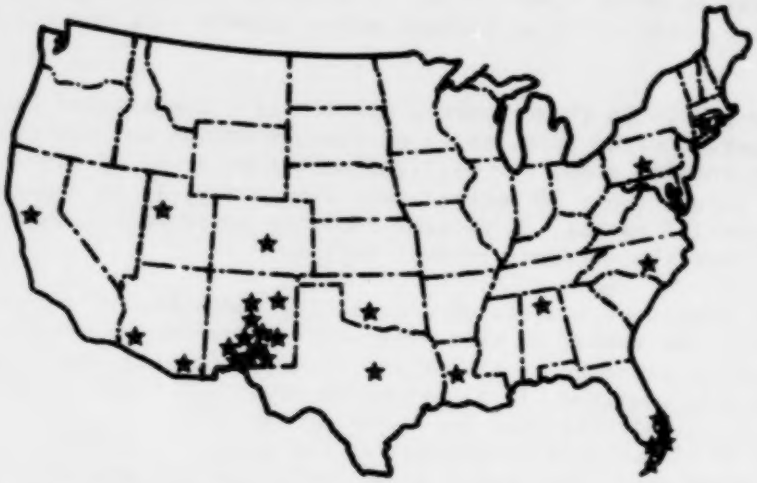
[53] The Technical Review of the Biological Effects of Non-Ionizing Radiation, prepared for the Office of Science and Technology Policy by an ad hoc Working Group, May 15, 1978, p. 15.

[54] Ibid, p. 13. Also Electronic Industries Association, Electronic Market Data Book: 1979, Washington, D.C., 1979.

[55] U.S. Senate, Committee on Commerce, Science, and Transportation, Hearings on Radiation Health and Safety, First Session on Oversight of Radiation Health and Safety, 95th Congress, June 16, 17, 27, 28 and 29, Serial No. 95-49, Washington, D.C., U.S. Government Printing Office, 1977, p. 349.



Source: U.S. Senate, Committee on Commerce, Science, and Transportation, Hearings on Radiation Health and Safety, 95th Congress, 1st Session, Serial No. 95-49, Washington, D.C., U.S. Government Printing Office, June 1977.

FIGURE 12-9
HIGH POWER ARMY TRANSMITTERS

12.3.6 Effects and Implications

The biological effects of nonionizing radiation have been of modest concern to scientists for many years. However, it is only in the last 10 years that public interest has led to an expanding research program to detect and evaluate these effects, especially nonthermal effects, and the program is still relatively small. Recent research has indicated that five areas should receive the highest priority in future investigations:[56]

- the nervous system
- growth and developmental mechanisms
- membrane structure and function

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[56] U.S. Environmental Protection Agency, Office of Research and Development, Research Outlook 1980, EPA 600/9 80-006, Washington, D.C., February 1980, pp. 143-149.

- o the immunological system
- o thermal physiology

Other areas of concern include behavioral, cardiovascular, reproductive, ocular, and other environmental effects.

Much of the U.S. research on radiation effects has been done on moderate to high power levels (5 mW/cm^2 and above). Average power density, frequency, and duration of exposure are the most important factors in energy absorption, which is the most important factor in determining health effects of radiation. The following section deals with the health effects of nonionizing radiation at levels both above and below 10 mW/cm^2. A later subsection on regulatory standards discusses further the possible effects of these lower levels of exposure.

Health Effects of Microwaves and Radio Waves

The most immediate and obvious effects upon the human body from exposure to microwave and radiowave radiation may be heat-induced. At frequencies between 30 MHz and 3 GHz (wavelengths from 10 cm to 10 m), radiation can penetrate the skin and raise the temperature of subsurface tissues, membranes, and organs. Lower frequency radiation causes little effect, and higher frequency radiation can hardly penetrate the skin. Burns, eye cataracts, and gonadal damage have been observed in animals which have had overdoses to high power levels.[57] Human studies are sparse, but there is some clinical evidence in the work of Dr. M. Zaret on cataract formation, as cited in the work of P. Brodeur (see reference 61). However, animal studies at comparable power levels have not verified this effect.

Animal studies also provide evidence for numerous nonthermal effects of microwaves and radio waves upon the central nervous system, the cellular systems, and the behavioral, immunological, biochemical, physiological, genetic, and development mechanisms.[58] However, it will take further research to determine whether or not these effects cause irreversible cellular damage or other harmful changes.

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[57] U.S. Department of Energy, Compilation and Assessment of Microwave Bioeffects, Final Report: Selective Review of the Literature on the Biological Effects of Microwave in Relation to the Satellite Power System, PNL-2634, May 1978, pp. 9-11.

[58] The Technical Review of the Biological Effects of Non-Ionizing Radiation, prepared for the Office of Science and Technology Policy by an ad hoc working group, April 15, 1978, pp. 48 and 49, also, U.S. Senate, Committee on Commerce, Science, and Transportation, Hearings on Radiation Health and Safety, First Session on Oversight of Radiation Health and Safety, 95th Congress, June 16, 17, 27, 28 and 29, 1977, Serial No. 95-49, Washington, D.C., U.S. Government Printing Office, 1977, p. 444.

Health Effects of High Voltage Transmission Lines[59]

High voltage transmission lines are a source of electromagnetic fields within the 0-Hz to 300-Hz frequency range. Although these are quite local, they are a concern because the electric and magnetic fields that surround high voltage transmission lines may affect biological systems. Healthy individuals experience nerve stimulation and tingling body sensations when exposed to high strength 60-Hz electric fields. Induced spark discharges are an annoyance to people near high voltage transmission lines that produce an electric field of strength greater than 8 to 10 kilovolts per meter. Maximum ground level fields under a 765 kilovolt line are 9 to 10 kilovolts per meter, dropping to 2 kilovolts per meter at the edge of the right-of-way. Adverse biological effects such as reduced growth rates and behavioral changes have been reported in animals but not in humans. Studies in the U.S.S.R. have reported nervous system and behavioral effects at fields as low as 1 kilovolt per meter. Scientists at DOE and EPA are investigating whether any adverse biological or ecological effects can be associated with electric and magnetic fields produced by high voltage transmissions lines.

Health Effects of Ultraviolet

Solar ultraviolet radiation is associated with skin cancer, and chronic exposure to near-ultraviolet has been implicated as a cause of cataracts. People working outdoors in sunlight may develop skin tumors, some of which may turn malignant. Less dangerous manifestations are sunburn and general skin irritation. Solar ultraviolet radiation is discussed in Chapter 5, Global Atmospheric Pollution, in the stratospheric ozone section.

Artificial ultraviolet radiation has been used therapeutically for treatment and prevention of rickets and for psoriasis therapy, for surface sterilization, and for killing bacteria and molds. A potential eye hazard exists for individuals who work in sterile "clean" rooms.

Health Effects of Visible Light

Visible light does not ordinarily present an environmental problem. Bright light causes physiological responses in the eye (pupillary reflex and eyelid closure) but generally leads only to discomfort, eye fatigue, or temporary vision interference.

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[59] The Technical Review of the Biological Effects of Non-Ionizing Radiation, prepared for the Office of Science and Technology Policy by an ad hoc working group, May 15, 1978, pp. 48-49.

On the other hand, lasers can produce narrowly focused radiation of very high intensity, which can damage the retina of the eye if one is not careful to avoid looking into the beam.

Health Effects of Infrared Light

The shorter wavelength part of the infrared spectrum can injure the cornea, iris, retina, and lens of the eye. Excessive exposure can cause cataracts in the eye by overheating.[60] Infrared sources are not in widespread civilian use, except for heat or sun lamps.

Regulatory Standards for RF and Microwaves

A variety of health effects have been observed to be caused by exposures to radiofrequency and microwave radiation, including burns, cataracts, and temporary sterility.[61] These effects appear at relatively high levels of exposure, above 10 mW/cm^2.[62] Research to date has documented these effects.

The U.S. occupational exposure guideline for microwave radiation is 10 mW/cm^2. Higher levels are allowed for exposures shorter than 6 minutes. The Soviet Union and Poland specify permissible occupational exposures of 0.01 mW/cm^2 and 0.2 mW/cm^2, respectively. Figure 12-10 indicates the relationship between the U.S. exposure guidelines and the U.S.S.R. exposure standard for microwave radiation, and a comparison with the U.S. emission standard for radiation emitted from microwave ovens. The Soviet public exposure standard is 0.001 mW/cm^2. The Soviet and Polish standards are more stringent than the American standard because the American standard is based primarily on the cooling capability of the body (i.e., thermal effects), whereas the Soviet and Polish standards are based primarily on neurological and behaviorial effects.[63] Meanwhile, Canada is considering a revised occupational standard of 1 mW/cm^2.

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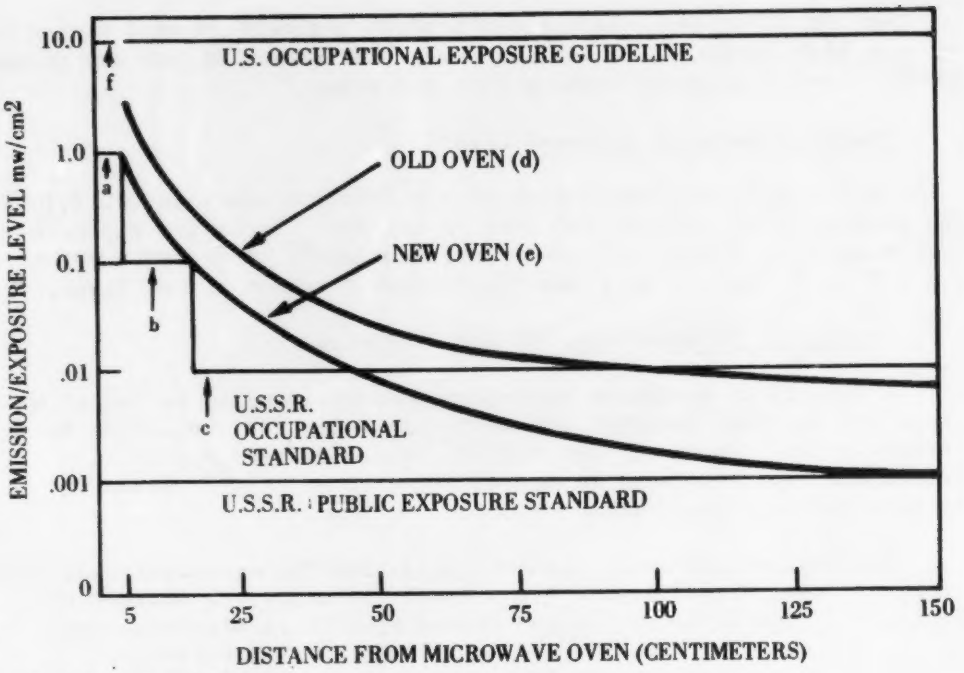
[60] Seymour Z., "Review Article: Near-UV Light and Cataracts," Photochemistry and Photobiology, Vol. 26, October 1977, pp. 437-441.

[61] Brodeur, P., The Zapping of America: Microwaves, Their Deadly Risk and the Cover-Up, W.W. Norton and Co., New York, 1977, pp. 37, 54-71, 198-201.

[62] Ibid.

[63] David Rall, Director, National Institute of Environmental Health Sciences, in U.S. Senate, Committee on Commerce, Science, and Transportation, Hearings on Radiation Health and Safety, First Session on Oversight of Radiation Health and Safety, 95th Congress, June 16, 17, 27, 28 and 29, 1977, Serial No. 95-49, Washington, D.C., U.S. Government Printing Office, 1977, p. 678.



a. Limit for times up to 15 minutes
b. Limit for times up to 2 hours
c. Limit for times greater than two hours
d. Used microwave oven emission - 5 mW/cm^2
e. New microwave oven emission - 1 mW/cm^2
f. Limit of 6 minutes fore exposure above 10 mW/cm^2

Note: The curves show that exposure of a person using a microwave oven for an eight hour work day would be well below the U.S. guideline. At a distance of 50 centimeters (100 centimeters for an older oven), the exposure would be equal to the U.S.S.R. standard.

Source: U.S. General Accounting Office, More Protection from Microwave Radiation Hazards Needed, Report by the Comptroller General of the United States, Washington, D.C., HRD-79-7, November 30, 1978, p. 16.

FIGURE 12-10
MICROWAVE EXPOSURE STANDARDS AND GUIDELINES

There is some evidence of health effects at levels of exposure below 10 mW/cm^2 but greater than 0.01 mW/cm^2,[64] reported primarily by investigators from Eastern European countries; however, the research results at these low power levels have not yet been confirmed in this country. It is hoped that research programs initiated to investigate the existence and significance of such effects will resolve this controversy.

Population Exposure

Several studies have been conducted to estimate the U.S. population's exposure to environmental nonionizing radiation. Table 12-11 indicates ambient radiation levels near certain major sources in the United States. Note that these levels are low compared to U.S. exposure standards, but not compared to Eastern European standards.

An EPA survey of metropolitan areas has shown that the average intensity of the nonionizing radiation to which the general public is exposed is 0.01 to 0.02 microwatts/cm^2, about a factor of 1,000 below even the U.S.S.R. occupational standard.[65] The survey estimates that only 0.5 percent are exposed to levels above the U.S.S.R. standard of 0.001 mW/cm^2. However, a more recent EPA survey indicates that the median exposure in urban areas is 0.005 mW/cm^2.[66]

Table 12-12 shows an EPA assessment of the percentages of the total U.S. population exposed to various levels of power density. The U.S. and U.S.S.R. protective standards are shown for comparison.

Eastern European countries have set their occupational exposure standards at low levels, supported by their data. The United States has set a voluntary occupational standard (mandatory for Federal employees) at a higher level, supported by EPA data. Controversy and questions abound and remain. What are the effects of low levels of nonionizing radiation? What is the health and ecological significance of these effects? What populations are actually affected?

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[64] U.S. General Accounting Office, More Protection from Microwave Radiation Hazards Needed, Report by the Comptroller General of the United States, Washington, D.C., HRD-79-7, November 30, 1978, p. 12.

[65] U.S. Senate, Committee on Commerce, Science, and Transportation, Hearings on Radiation Health and Safety, First Session on Oversight of Radiation Health and Safety, 95th Congress, June 16, 17, 27, 28 and 29, 1977, Serial No. 95-49. Washington, D.C., U.S. Government Printing Office, 1977, pp. 210 and 219.

[66] Janes, D.E., "Radiofrequency Environments in the United States," ICC 1979 Conference Record, Vol. II, Paper 31.4, IEEE Publication No. 79CH1435-7, New York, 1979.

TABLE 12-11
AMBIENT NONIONIZING RADIATION LEVELS

Location	Power Density (mW/cm^2)
Empire State Building, New York City[a]	
86th Floor Observatory	0.015
102nd Floor Observatory	0.031
Milam Building, Houston, Texas[a]	
47th Floor	0.036
Home Tower, San Diego, California[a]	
Roof	0.180
Broadcast Hill, Washington, D.C.[b] (Fessenden Street, NW)	0.003
Microwave Oven (less than 1 year old)	1.000
Traffic Radar (30 meters from driver)[c]	0.0003

Sources: a) Tell, R.A. and N.N. Hankin, Measurements of Radiofrequency Field Intensity in Buildings With Close Proximity to Broadcast Stations, EPA Publication ORP/EAD 78-3, Las Vegas, Nevada, August 1978; b) Athey, T.W. et al., Radiofrequency Radiation Levels and Population Exposures in Urban Areas of the Eastern United States: Technical Report, EPA-520/2-77-008, Silver Spring, Maryland, May 1978; and c) Janes, D.E., The EPA Environmental Radiofrequency Program: Present Status and Environmental Findings, presented at 1978 Joint Meeting of the Aerospace and Flight Test Radio Coordinating Council and the Frequency Managers Group, Range Commanders Council, Arlington, Virginia, October 14, 1978.

Assessment of all the implications and impacts is needed to assure the safe application and use of nonionizing radiation.

Other Environmental Impacts

Increased nonionizing radiation could have impacts on entire ecosystems. It has been suggested that bird migration could be disrupted; there is some evidence that birds are sensitive to electromagnetic radiation and that, in its presence, they alter their flight paths. Worldwide, low-frequency communication systems and the projected solar satellite power system are two specific sources of concern. Even though the impact of these sources is presently difficult to assess, they will expose one or more ecosystems to continuous and widespread nonionizing radiation.

TABLE 12-12
POPULATION EXPOSURES TO RADIOFREQUENCY/RADIATION

Power Density (mW/cm^2)		Cumulative Percentage of U.S. Population Exposed to Radiofrequency Radiation Greater than Level Specified
10.	(U.S. occupational standard)	--
1.0	(U.S. standard for microwave oven at 5 cm distance)	--
0.01	(U.S.S.R. occupational standard)	--
0.001	(U.S.S.R. public standard)	0.5
0.0005		1.0
0.0002		2.5
0.0001		5.0
0.00005		8.0
0.00001		31.0
0.000005		51.0

Source: Tell, R.A. and E.D. Mantiply, Population Exposure to VHF and UHF Broadcast Radiation in the United States, EPA Publication ORP/EAD 78-5, Las Vegas, Nevada, June 1978.

CHAPTER 13
NOISE

HIGHLIGHTS OF CHAPTER 13

- Noise-induced hearing loss, the nation's most prevalent occupationally induced disease, affects millions of persons presently working in manufacturing and construction occupations.
- Community noise levels are rising; millions of Americans are now subjected to daily noise levels beyond those deemed consistent with protection of the public health and welfare.
- Nonauditory health effects of noise, a problem for the general public, are not yet well understood. Within the general population, certain subgroups such as young children and older adults may be particularly susceptible.

13.1 INTRODUCTION

Noise is generally defined as unwanted sound. Throughout history, people have viewed noise as an annoyance or a nuisance and have made innumerable attempts to abate or control it, usually by prohibiting certain activities at various locations in the community or during certain times of the day or night. Recently, noise has been recognized as being an environmental pollutant having serious auditory and nonauditory health effects. Some of these health effects are just beginning to be identified and understood.

The following discussion of the noise pollution problem identifies its scope; highlights regulatory efforts at Federal, state, and local government levels; notes possible trends in noise exposure levels to the year 2000; and develops issues which appear to warrant further consideration.

13.1.1 Problem Identification

As a pervasive element in the urban environment, noise, both in the workplace and community, constitutes a recognized hazard to hearing and is a potential hazard to the health of other bodily systems. Noise affects our ability to function at school, at work, at home, and in the social environment.

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Noise-induced hearing loss has been established as the nation's most prevalent occupationally induced disease.[1] Estimates suggest that as many as 15 million production workers in manufacturing and utilities are subject to levels capable of causing noise-induced hearing impairment over their adult working lifetimes. This impairment is due to daily exposure to A-weighted equivalent sound levels[2] of 75 decibels (dB) or more.[3]

Nonoccupational or community noise poses an additional threat to the public health. Some studies suggest that the average person in a non-industrial job over the course of a week may have a 7-day average L_{eq} (24)[4] of about 75 dB.[5] In comparison, an L_{eq} (24) of 70 dB has been identified as the maximum noise level consistent with full protection of hearing, allowing for an adequate margin of safety.[6]

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[1] U.S. Environmental Protection Agency, Federal Interagency Noise Effects Research Panel, Federal Noise Research in Noise Effects, EPA 550/9-78-102, Washington, D.C., February 1978.

[2] The A-weighted sound level is one of several different scales of sound measurement which accounts for or weights frequencies with respect to the different frequency sensitivies of the ear at low levels. A-weighted sound levels are expressed in decibels on a logarithmic scale where the level of sound pressure is measured against a standard reference value of 0.0002 bars.

[3] Bolt, Beranek, and Newman, Inc., Economic Impact Assessment of the Proposed Noise Control Regulation, Report No. 3246, Cambridge, Massachusetts, April 21, 1976.

[4] L_{eq} (24) is a description of sound known as the equivalent sound level that in a stated period of time (here 24 hours denoted by [24]) would contain the same sound energy as the time-varying sound during the same time period. The L_{eq} measure incorporates the A-weighting system.

[5] Lieutenant Colonel Daniel Johnson of the Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, in a speech to the North Carolina Chapter of the Acoustical Society of America, November 10, 1978. Also, Shori, T.R. and E.A. McGatha, A Real-World Assessment of Noise Exposure, U.S. Environmental Protection Agency, Washington, D.C. 1978.

[6] U.S. Environmental Protection Agency, Office of Noise Abatement and Control, Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety, Pub. No. 550/9-74-004, Washington, D.C., March 1974. Exposure for a 40 year period to an L_{eq} (24) of 71.4 dB would produce a minimal hearing loss (less than 5dB at 4,000 Hz) for 96 percent of the population. This exposure level has been reduced by 1.4 dB in establishing a protective exposure level of 70 dB thus providing a margin of safety.

Exposure to high noise levels is known to cause hearing impairment; in addition, continuing research into the nonauditory effects of noise has produced a growing body of evidence that links noise either directly or indirectly to heart disease problems, diseases associated with stress, and mental illness. Exposure to extremely intense sound can cause loss of balance and dizziness due to malfunctions of the inner ear, and workers in intensely noisy places have been found to lose their peripheral vision and develop cardiovascular irregularities.[7] Levels producing these effects, however, rarely occur in the general environment. Noise also interferes with the quantity and quality of sleep, which in turn affects the individual's feelings of well-being and, over an extended period of time, may affect mental and physical health.[8]

Noise has also been shown to have other detrimental effects upon the public health and welfare. Children exposed to daily noisy environments may experience difficulty with language development, reading ability, and their general performance in school.[9] Adults subjected to loud or intermittent noise in the workplace may find their work efficiency hampered.[10] In the community, excessive noise interferes with conversation and social interaction.

13.1.2 Regulatory Background and Research

Noise abatement and control activities occur at the Federal, state, and local levels of government. Generally, the Federal role includes identifying noise exposure levels necessary to protect the public health and welfare, regulating noise emissions from newly manufactured products and activities, enforcing regulations, and providing research and technical assistance. The state and local government roles include regulating noise emissions from products and activities, and to the extent that this role has not already been preempted at the Federal level, regulating emissions from newly manufactured products.

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[7] Cohan, A., "Extraauditory Effects," in Handbook of Physiology Vol. 9: Reaction to Environmental Agents.

[8] U.S. Environmental Protection Agency, Office of Noise Abatement and Control, Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety. Publication number 550/9-74-004, Washington, D.C., March 1974.

[9] Millis, J.H. "Noise and Children - A Review of the Literature" Journal of the Acoustical Society of America, Vol 56, p. 767-779, March 1974.

[10] National Institute for Occupational Safety and Health, Criteria for a Recommended Standard: Occupational Exposure to Noise, Pub. No. PB-213 463, Rockville, Maryland, 1972.

Federal Regulation and Research

The Noise Pollution and Abatement Act of 1970 (PL 91-604) was the first legislation to provide a central focus for overall environmental noise abatement at the Federal level.[11] This Act established the Office of Noise Abatement and Control for the purpose of conducting a full and complete investigation of noise and its effects on public health and welfare. Information gathered in this investigation provided a basis for the first national noise control legislation, the Noise Control Act of 1972 (PL 92-574).

Before enactment of the 1970 legislation, Federal statutes had been directed toward noise abatement for specific sources, such as aircraft noise under the 1968 Amendments to the Federal Aviation Act of 1958 (PL 90-411) or in regard to special environmental situations, such as occupational exposure under the Walsh-Healey Public Contracts Act.[12] Under the 1972 legislation, EPA was mandated to:

- Develop and publish noise exposure criteria
- Identify major sources of noise and regulate these sources
- Propose aircraft noise standards to the Federal Aviation Administration
- Require the labeling of noisy and noise-reducing products
- Engage in research, technical assistance, and dissemination of public information
- Coordinate all Federal noise control efforts.

As EPA acted on this mandate, it became evident that although effective noise source regulations at the national level were needed, those regulations would have to be accompanied by effective noise control programs at the state and local levels.[13] Consequently, with passage of the Quiet Communities Act of 1978 (PL 95-609), EPA's role in aiding states and localities in establishing noise control programs and in providing the public with information on the harmful effects of noise was greatly expanded. Specifically, the 1978 legislation mandated the Environmental Protection Agency to fund, through grants, cooperative agreements, or contracts, the following:

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[11] U.S. Environmental Protection Agency, Report to the President and Congress on Noise, Pub. No. PB 206-716, Washington, D.C., December 31, 1971.

[12] Walsh-Healey Public Contracts Act, 41 U.S.C. 35 et seq.

[13] U.S. Environmental Protection Agency, Office of Noise Abatement and Control, Toward a National Strategy for Noise Control, Washington, D.C., April, 1977.

- Financial assistance to states and localities for
  - problem identification--noise control capacity building
  - transportation noise abatement
  - evaluation and demonstration of noise control techniques
- Preparation of model state and local legislation
- A state and local noise control research and demonstration program
- Establishment of regional technical assistance centers
- Provision of assistance in staffing and training for state and local programs
- A national environmental noise assessment
- Increased noise research, especially in the area of non-auditory effects.

In keeping with the mandates in the 1972 and 1978 legislation, EPA has identified major noise sources and is now developing noise emission standards for several noise-producing products. Final regulations have been issued on newly manufactured portable air compressors[14] and on medium- and heavy-duty trucks,[15] and garbage trucks.[16] Proposed regulations have been issued for new wheel and crawler tractors,[17] new buses,[18] new motorcycles and motorcycle replacement exhaust systems,[19] with other product regulations still in the development stage. In addition, EPA has promulgated noise emission standards for in-use railroad equipment and motor carriers (over 10,000 pounds gross vehicle weight) operating in interstate commerce.[20]

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[14] U.S. Environmental Protection Agency, Noise Emission Standards for Portable Air Compressors, 40 CFR, Part 204, 41 FR 2162, January 14, 1976 as amended.

[15] U.S. Environmental Protection Agency, Noise Emission Standards for Medium and Heavy Trucks, 40 CFR, Part 205, Subparts A and B, 41 FR 15538, April 13, 1976, as amended.

[16] U.S. Environmental Protection Agency, Noise Emission Standards for Truck Mounted Solid Waste Compactors, 44 FR 56524, October 1, 1979.

The Occupational Safety and Health Act of 1970, amended in 1974 (PL 93-237) also has a bearing on noise exposure. This legislation applies the noise exposure standards promulgated under the Walsh-Healey Act and the Service Control Act of 1965 to all businesses engaged in interstate commerce. A standard of 90 decibels for an eight-hour day is now being enforced.

Various Federal agencies, including the Department of Transportation (DOT), Department of Defense (DOD), and Department of Housing and Urban Development (HUD), have adopted noise abatement and control policies consistent with the legislation discussed in this section. Within DOT, the Federal Highway Administration has sought to control noise exposure by incorporating noise considerations in highway location and design decisions, although noise control is only one factor and may be outweighed by other considerations.

Another DOT agency, the Federal Aviation Administration, has policies in effect to reduce aviation noise by: source noise reduction through aircraft retrofit/replacement; modifications in take-off and landing procedures; and development plans for airport noise control and land use compatibility controls. These last measures regarding land use have the objective of containing severe noise impacts within airport-controlled areas through purchase of land, purchase of easements for development rights, changes in land use from noise-sensitive to noise-tolerant uses, and prevention of new incompatible uses.[21]

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[17] U.S. Environmental Protection Agency, Proposed Noise Emission Standards for New Wheel and Crawler Tractors, 42 FR 35804, July 11, 1977.

[18] U.S. Environmental Protection Agency, Proposed Noise Emission Standards for Buses, 42 FR 45776, September 12, 1977.

[19] U.S. Environmental Protection Agency, Proposed Noise Emission Standards for Motorcycle and Motorcycle Replacement Exhaust Systems, 43 FR 10822, March 15, 1978.

[20] U.S. Environmental Protection Agency, Railroad Noise Emission Standards, 41 FR 2184, Jan. 14, 1976; Noise Emission Standards for Transportation Equipment; Interstate Rail Carriers, 45 FR 1252, January 4, 1980; Noise Emission Standards for Interstate Motor Carriers, 39 FR 38208, Oct. 29, 1974.

DOD, under its Air Installations Compatible Use Zones (AICUZ) program, has adopted a similar approach for dealing with military aircraft noise. However, the principal tool of this program has been technical assistance to communities in preparing and enacting land use planning controls to ensure that local development will be compatible with the noise levels and accident threat generated by an airfield. DOD has also adopted a more stringent occupational noise exposure standard (i.e., 85 dB over a period of 8 hours: L_{eq} (8) = 85 dB) than that currently in force under the Occupational Safety and Health Act (i.e., Daily Noise Dose equivalent to 90 dB over a period of 8 hours).

HUD's noise policy restricts assistance to housing developments that meet a series of internal and external noise standards. However, the overall effectiveness of this policy is limited since HUD mortgage guarantees and assistance apply to only 5 to 10 percent of the national housing market.

Prior to the passage of the Noise Control Act of 1972, individual Federal agencies had ongoing research, development and demonstration activities related to noise abatement and control. These activities were, and largely continue to be, oriented toward satisfying each agency's statutory mandates and needs, operational authorities, goals and objectives. Independent efforts have been carried out in the areas of aviation and surface transportation noise, machinery and construction equipment noise, community exposure and noise effects.

Recently, EPA's Office of Noise Abatement and Control has developed a five-year noise effects research plan. Research priority areas within the plan include:

- Nonauditory physiological effects especially related to stress diseases
- Sleep disturbance
- Noise induced hearing loss
- Behavioral, social and performance effects

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[21] U.S. Department of Transportation, Federal Aviation Administration, Airport-Land Use Compatibility Planning, Pub. No. AC/150/5050-6, Washington, D.C., 1977.

- Communications interference

- The effects of noise on wildlife and other animals

In the past, noise research has centered upon noise induced hearing loss. With adoption of this five year plan, EPA will place more emphasis on research where the consequences of noise exposure are less understood.

State and Local Regulation

By 1978, approximately 40 states and 1,200 municipalities had adopted some form of noise control legislation. At the state level, statutes generally regulate noise from airport operations and from motor vehicles and, to a lesser extent, from snowmobiles and motorboats. States also regulate occupational noise through enforcement of standards included in the Occupational Safety and Health Act. Other areas covered by state regulations include construction site noise, acoustical treatment of buildings, and, to a very limited extent, industrial and commercial noise emission levels.

Municipal regulation of transportation and occupational noise, as well as acoustical treatment of buildings, is comparable to that found at the state level. However, industrial, commercial, construction, and domestic (i.e., household) noises are much more heavily regulated at the local level through nuisance ordinances and zoning restrictions, which apply not only to sound emission levels but also to hours of operation.

Although it appears that state and local regulation is extensive, in many instances noise control ordinances are not actively enforced. However, where they are enforced by well trained personnel the ordinances can be quite effective. Under the Quiet Community Act Amendments of 1978, EPA is helping a number of communities initiate and strengthen noise control programs.

13.2 IMPACTS AND TRENDS

13.2.1 Noise Sources and Existing Levels

Noise sources are to be found everywhere in our environment. For discussion purposes, environmental noise can be classified as transportation noise, occupational or industrial noise, and community and household background noise.

The two significant sources of transportation noise are air traffic and surface traffic. Present estimates are that more than 5 million people living in the vicinity of our nation's airports are subjected to noise levels of L_{dn} = 65 dB or more.[22] Noise exposure at this level is significant in that it exceeds the L_{dn} 55 level identified by EPA as being protective of the public health and welfare with an adequate margin of safety.[23] Surface traffic noise, generated primarily by automobiles and trucks, ranges from 70 to 95 dB when measured at a distance of 50 feet. Surface traffic is highly pervasive in the urban environment and is continually identified as the most frequently annoying.[24]

Occupational noise from machine operations and construction activities is generally the most intense. Typical machine noise levels, by industry, are included in Table 13-1, while 1976 estimates of the numbers of workers exposed to noise levels of 85 dB and above are provided in Table 13-2.

Annoying noise sources in the community and home include transportation noise, domestic noise from operation of home and garden appliances, and noise from commercial and industrial activities. Typical maximum and minimum daily noise levels in city and suburban locations are presented in Table 13-3, and estimated percentages of the urban population exposed to various day-night noise levels are presented in Table 13-4. The data in Table 13-4 indicate more than 50 percent of the urban population, or 93 million people, are subject to day-night noise levels of general urban noise that exceed the L_{dn} 55 protective level established by EPA. (Table 13-4 does not include persons whose residences are located close to primary noise sources such as airports, highways or construction sites.)

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[22] The Day-Night Sound Level, designated L_{dn}, is the A-weighted equivalent sound level for a 24-hour period with an additional 10 dB weighting imposed on the equivalent sound levels (L_{eq}) occurring during nighttime hours, 10 p.m. to 7 a.m. See Wyle Laboratories, Noise Exposure of Civil Aircarrier Airplanes Through the Year 2000. Vol. 1: Methods, Procedures, Results, Pub. No. 550/9-79-313-1, Washington D.C., EPA Office of Noise Abatement and Control, February 1979.

[23] U.S. Environmental Protection Agency, Office of Noise Abatement and Control, Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Marginal Safety, Pub. No. 550/9-74-004, Washington, D.C., March 1974.

[24] Kaiser, E.J. et al., Promoting Environmental Quality Through Urban Planning and Controls, Pub. No. EPA 600/5-73-015, Washington, D.C., U.S. Environmental Protection Agency, February 1974.

TABLE 13-1
SUMMARY OF MACHINE NOISE BY INDUSTRY

SIC Code	Industry	Number of Machine Types Identified	Number of Machine Types With SPL Data	Mean SPL for Machine Types, dBA
16	Construction	36	19	85 (109[a])
20	Food and Kindred Products	42	18	94
21	Tobacco Manufacturers	6	0	N.A.
22	Textile Mill Products	15	10	93
23	Apparel and Related Products		Included in SIC 22	
24	Lumber and Wood Products	15	11	96
25	Furniture and Fixtures		Included in SIC 24	
26	Paper and Allied Products	21	9	91
27	Printing, Publishing, and Allied Products	22	11	90
28	Chemical and Allied Products	15	15	88
29	Petroleum and Coal Products	29	7	99
30	Rubber and Miscellaneous Plastic Products		Included in SIC 28	
31	Leather and Leather Goods	10	10	85
32	Stone, Clay, and Glass Products	12	12	91
33	Primary Metal Industries	38	38	98
34	Fabricated Metal Products	41	27	99
35	Machinery Except Electric	21	17	101
36	Electrical and Electronic Machinery	13	12	99
37	Transportation Equipment	13	12	99
49	Utilities	8	8	95
		357	236	

[a] SPL (Sound Pressure Level) adjusted from 50 feet to 3 feet.

Source: Bergmann, E.P., Severe Sources of Industrial Machinery Noises, LIT Research Institute, prepared for U.S. Environmental Protection Agency, Contract No. 68-01-2234, Chicago, Illinois, 1974.

TABLE 13-2
ESTIMATE OF THE NUMBER AND PERCENTAGE OF PRODUCTION WORKERS OVEREXPOSED TO NOISE

Industry	SIC Code Code	Production workers (Thousands)	Overexposed Workers (Thousands) 85 dBA	90 dBA	Percentage Overexposed 85 dBA	90 dBA
Food	20	1170	820	350	70	30
Tobacco	21	63	48	40	76	63
Textiles	22	900	855	765	95	85
Apparel	23	1174	12	0	1	0
Lumber and wood	24	542	542	390	100	72
Furniture and fixtures	25	427	235	58	55	15
Paper	26	557	395	206	71	37
Printing and Publishing	27	661	132	99	20	15
Chemicals	28	596	137	66	23	11
Petroleum and Coal	29	117	58	23	50	20
Rubber and plastics	30	531	266	106	50	20
Leather	31	256	3	0	1	0
Stone, clay, and glass	32	555	416	139	75	25
Primary Metals	33	989	577	259	58	26
Primary steel	331	485	325	170	67	35
Foundries	332 336	275	189	54	70	20
Primary nonferrous	333, 334, 335	233	63	35	27	15
Fabricated metals	34	1123	786	225	70	20
Machinery except electrical	35	1366	956	273	70	20
Electrical Machinery	36	1370	959	274	70	20
Transportation equipment	37	1354	880	284	65	21
Utilities	49	627	445	188	71	30
Total		14,382	8,524	3,755		
Total Average					59.3	26.1

Note: The majority of these estimates are the result of informal discussions with industry spokesmen who were willing to discuss the subject. There is very little definitive information available therefore, these estimates should be viewed as best guesses. U.S. Department of Labor, Bureau of Labor Statistics, Employment and Earnings, Vol. 20, No. 2, August 1973.

Source: Bolt, Beranek and Newman, Inc., Impact of Noise Control at the Workplace, Report No. 2671, Cambridge, Mass., January 1974, p. C-2. Used with permission.

TABLE 13-3
COMPARISON OF MAXIMUM DAYTIME AND MINIMUM NIGHTTIME HOURLY OUTDOOR NOISE LEVELS IN CITY AND IN DETACHED HOUSING RESIDENTIAL AREAS

	Maximum Daytime Hour 0700 - 1900			Minimum Nighttime Hour 2200 - 0700			Difference Between Day and Night	
General Category	Range (dBA)	Arithmetic Mean (dBA)	Standard Deviation (dB)	Range (dBA)	Arithmetic Mean (dBA)	Standard Deviation (dB)	Mean Difference (dB)	Standard Deviation of Difference (dB)
Residual Noise Level (L_{90})								
City (4 Locations)	62 to 79	71	6.9	47 to 59	56	5.6	15	2.7
Suburban and Urban Detached Housing Residential (11 Locations)	42 to 56	49	4.3	27 to 42	36	5.5	13	4.4
Median Noise Level (L_{50})								
City (4 Locations)	66 to 83	76	7.2	51 to 70	62	7.1	14	4.0
Suburban and Urban Detached Housing Residential (11 Locations)	46 to 61	55	4.1	31 to 46	39	5.3	16	4.0

Source: Wyle Laboratories, Community Noise, Pub. No. NIID 300.3, prepared for and published by EPA Office of Noise Abatement and Control, Washington, D.C., 1971.

TABLE 13-4
ESTIMATED PERCENTAGE OF URBAN POPULATION RESIDING IN AREAS WITH VARIOUS DAY-NIGHT NOISE LEVELS TOGETHER WITH CUSTOMARY QUALITATIVE DESCRIPTION OF THE AREA[a]

Description	Typical Range of L_{dn}, dB	Average L_{dn}, dB	Estimated Percentage of Urban Population	Average Census Tract Population Density, No. of people/mi^2
Quiet suburban residential	48-53	50	12	630
Normal suburban residential	53-58	55	21	2,000
Urban residential	58-63	60	28	6,300
Noisy urban residential	63-68	65	19	20,000
Very noisy urban residential	68-73	70	7	63,000

[a] These values do not reflect exposure to aircraft and highway noise.

Source: U.S. Environmental Protection Agency, Office of Noise Abatement and Control, Population Distribution of the United States as a Function of Outdoor Noise Levels, Pub. No. SSS/9-74 009 A&B, Washington, D.C., June 1974.

13.2.2 Trends in Noise Exposure Levels

The data presented in the preceding sections imply that a substantial portion of the nation's population is regularly subjected to noise levels potentially damaging to the public health and welfare. Assuming continued population and economic growth, the number of noise generating activities will also increase. However, with adequate regulation and improved noise control technologies, such increases need not translate into higher noise levels.

In the area of transportation, perhaps the greatest potential for realizing noise reduction lies in decreasing aircraft-related noise. Annual commercial jet aircraft operations (take-offs or landings) at the nation's airports are projected to rise from 8.3 million in 1975 to 21.5 million in 2000, an increase of 160 percent.[25] Over the same time period, the numbers of people exposed to day-night (L_{dn}) noise levels of 65 dB or more are expected to decrease, as noted in Table 13-5. The decreases noted in Table 13-5 are contingent upon full compliance with present aircraft noise certification rules[26] and those proposed by the Environmental Protection Agency for 1980 and 1985.

In surface transportation, automobile and truck traffic, total annual vehicle miles of automobile and truck travel are expected to increase from a 1975 level of 2.3×10^{12} miles to 3.2×10^{12} miles under the Low Growth Scenario and to 5.1×10^{12} miles under the High Growth Scenario for the year 2000, representing increases of 39 percent and 122 percent, respectively. These estimates do not reflect possible changes resulting from an increasing scarcity of gasoline. While changes in noise levels cannot be estimated directly, it can be stated generally that there is an increase in roadway noise of 3 dB with each doubling in traffic volume.[27] EPA noise regulations regarding new medium- and heavy-duty trucks and expected reductions in tire noise should offset these anticipated increases in roadway noise to some degree.

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[25] Wyle Laboratories, Noise Exposure of Civil Aircarrier Airplanes Through the Year 2000. Vol. 1: Methods, Procedures, Results, Pub. No. 550/9-79-313-1, EPA Office of Noise Abatement and Control, Washington D.C., February 1979.

[26] Federal Aviation Administration, Noise Standards, 14 C.F.R., Part 36, January 1969.

[27] Institute of Transportation Engineers, Transportation and Traffic Engineering Handbook, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1976.

TABLE 13-5
SUMMARY OF ESTIMATED REDUCTION IN NOISE EXPOSURE FROM AIRCRAFT WITHIN L_{dn} 65 dB CONTOUR BY YEAR 2000 AS A FUNCTION OF APPLIED TECHNOLOGY LEVEL

			Exposure Within L_{dn}65 Contour			
			Area		Population	
Year	Technology Level	Certification Rule	Mi^2	Percent	10^6 People	Percent
1975	Base	1969 FAR Part 36	2,169	100	6.17	100
2000	1	1975 FAR Part 36[a]	1,304	60	3.58	58
2000	2	1980 Proposed EPA Rule	1,200	55	3.11	50
2000	3	1985 Proposed EPA Rule	1,157	53	2.95	48
2000	3A[b]	1985 Proposed EPA Rule	626	29	0.92	15

[a] Stage 3 in FAR Part 36 Terminology.

[b] All aircraft assumed to comply with noise levels specified by the 1985 Proposed Rule.

Source: Wyle Laboratories, Noise Exposure of Civil Aircarriers Airplanes Through the Year 2000. Vol. 1, Methods, Procedures, Results, Pub. No. 550/9-79-313-1, prepared for and published by EPA Office of Noise Abatement and Control, Washington, D.C., February 1979.

During the next 20 years, some of the factors influencing noise levels in the workplace are expected to change. These factors include new industrial technologies and work practices, fuller compliance with current OSHA noise exposure standards, and possible adoption of more stringent standards. The effect that each of these changes could have on industrial noise levels cannot be predicted at present. Thus, while it is estimated that the number of industrial workers will double between 1975 and 2000 to roughly 25 million,[28] the number of overexposed workers cannot be determined.

More that 100 million people in the United States are exposed on any one day to noise levels greater than Ldn 55 from construction noise. There are more than 2.4 million active construction sites including residential, mixed residential/commercial, industrial, and public works projects. This number does not include active highway and street construction sites which would add many thousands more sites. Although the number of construction sites will vary from year to year between now and the year 2000 because of the construction industry's sensitivity to national economic conditions, a significant upward trend in construction sites is not anticipated nor are significant shifts anticipated in population density near construction sites. However, a continuing transition is occurring from small size equipment to larger, more powerful units in an effort to increase productivity and decrease overall construction costs. This trend brings with it higher noise levels and attendant increases in the severity and extensiveness of construction site noise impacts. However, existing and proposed EPA regulations for trucks and construction equipment would have a moderating influence on these increases.

With projected growth of transportation and other noise sources, community background noise levels could rise. This indeed would be the case where land use changes did occur, such as from rural to suburban. Under such changes, ambient noise levels could increase by 10 dB or more to approximately the levels noted in Table 13-4. Using the 1972 OBERS (Series E) population projections, approximately 196 million people living in the nation's standard metropolitan statistical areas in 2000 would be subject to these levels. However, where no appreciable land use changes occurred, noise levels would most likely remain the same.[29]

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[28] U.S. Water Resources Council, 1972 OBERS Projections of Economic Activity in the U.S.: Vol. 4, States, Washington, D.C., April 1974.

[29] Wyle Laboratories, Community Noise, Pub. No. NTID 300.3, EPA Office of Noise Abatement and Control, Washington, D.C., December 31, 1971.

13.3 ISSUES AND IMPLICATIONS

13.3.1 Noise-Induced Hearing Loss

Over 15 million Americans are exposed to levels of noise in the workplace capable of causing hearing loss (i.e., $L_{eq}(8) = 75$ dB), the nation's most prevalent occupationally induced disease. Under the current OSHA and Department of Labor 8-hour noise exposure standard of 90 dB, as many as 25 percent of the exposed population receive the lower limit of a daily dose sufficient to produce socially handicapping loss of hearing.

In 1972, the National Institute for Occupational Safety and Health recommended that the 8-hour standard of 90 A-weighted decibels be reduced to 85 decibels.[30] When the Occupational Health and Safety Administration indicated that it intended to repromulgate a 90 decibel standard, EPA challenged. This OSHA action and an extensive set of hearings on the need for an 85 decibel standard and its actual feasibility followed. No final decision on the standard has been reached. Consequently, the 8-hour exposure standard remains at 90 dB. Thus, 25 percent of the exposed population could be subject to handicapping loss of hearing, while under the 85-dB noise standard, this percentage would be reduced to 12 percent. However, the economic and technological feasibility of this 5-dB reduction remains unsettled.

One notable exception to the Federal standard of 90 decibels is an action by the Department of Defense. In 1978, DOD issued Instruction Number 6055.3 establishing a uniform hearing conservation program with the goal of eliminating all occupational noise-related hearing loss among defense personnel. The 85 dB exposure limit has been set as the goal of this program.

Outside the workplace, noise levels are also high; taking into account daily exposure from all sources, the average American in a relatively quiet job may be subject to a 7-day average $L_{eq}(24)$ of 75 dB. This exposure level is 5 dB higher than the 24-hour yearly hearing protective level of 70 dB and approaches $L_{eq}(24) = 77$ dB, at which only 50 percent of the population would be protected.[31]

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[30] National Institute for Occupational Safety and Health, Criteria for a Recommended Standard, Occupational Exposure to Noise, Pub. No. 213-463, Rockville, Maryland, 1972.

[31] U.S. Environmental Protection Agency, Office of Noise Abatement and Control, Protective Noise Levels, Condensed Version of EPA Levels Document, Pub. No. EPA 550/9-79-100, Washington, D.C., November 1979.

Persons who work in noisier environments will experience 24-hour exposures in excess of this level.

13.3.2 Other Effects

Considerable research has been done on nonauditory health effects of noise; however, to date, no human illness other than hearing loss is known to be directly caused by noise.[32] Nevertheless, studies consistently and clearly associate noise with physiological and psychological stress diseases such as heart disease and high blood pressure. Noise interferes with aural communications on the job, in schools, in the home and elsewhere. It may affect children's ability to learn and adults' work efficiency. It can disrupt sleep and possibly degrade health and performance generally.

Biomedical and behavioral research has identified some health hazards stemming from noise; still, some specific links have yet to be established, and thus the question of what levels of noise produce specific health effects has not been answered. For example, subgroups in the general population may be particularly sensitive to noise effects. Among these possibly susceptible groups are the elderly, unborn children in various stages of fetal development, young children, persons already ill or at risk due to other causes, and mentally and emotionally ill persons.

13.3.3 Noise Control Regulation

Effective noise abatement and control involves Federal, state, and local government levels. The Federal government can sponsor research and develop regulations governing products and activities, but successful noise control also requires state and local action in adopting and enforcing effective noise ordinances. Land use planning is also important. Many past efforts at noise control by state and local governments have been directed at nuisance abatement, but an increasing number have enacted numeric standards to control products and facilities in use. As knowledge of the importance of noise as a pollutant and the means to control it are communicated to communities and as new communities enact ordinances fortified by the Quiet Communities Act of 1978, we can expect state and local efforts to curb the rise in noise levels to become increasingly effective.

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[32] U.S. Environmental Protection Agency, Office of Noise Abatement and Control, Noise: A Health Problem, Washington, D.C., August 1978.

CHAPTER 14
ENERGY AND THE ENVIRONMENT

HIGHLIGHTS OF CHAPTER 14

- Under high economic growth conditions, four major energy-related problems would be expected by the year 2000:
  - Continued high levels of sulfur oxide emissions
  - Substantial growth in nitrogen oxide emission levels
  - Large increases in solid waste generation
  - Impacts associated with synthetic fuel production
- Projected increases in the use of coal by utilities and industries by 2000 largely account for the sulfur oxide and nitrogen oxide projections, and they substantially contribute to the anticipated increase in solid waste.
- The production and use of synthetic fuels from oil shale are projected to be major sources of solid waste by 2000. The probable concentration of these industries in the Mountain Region (Federal Region VIII) would place a heavy environmental burden on this area, much of which is now relatively pristine.
- With slower economic growth, all of the major environmental problems identified with high growth would be expected to occur, but to a lesser degree.
- Conservation of energy and increased use of solar energy technologies could significantly mitigate the energy-related environmental consequences of high economic growth, particularly if these measures reduced the demand for coal and synthetic fuels.

14.1 INTRODUCTION

In the preceding chapters, energy has been identified as one, often major, source of environmental pollutants. The relationship between energy and environmental quality is both direct and intimate; therefore, our energy future will significantly affect our environmental future. The purpose of this chapter is to summarize selected environmental consequences of several alternative energy futures.

We focused generally on those energy impacts that are most influenced by different assumptions about future energy supply, conversion, and demand in the future. Several important consequences of energy production - oil spills, nuclear wastes and pipeline ruptures - are not discussed because of their relative insensitivity to alternative energy futures. The discussion begins with the environmental consequences associated with the rather conventional energy futures implied by the High Growth and Low Growth scenario assumptions described in Chapter 2.

14.1.1 Scenario Assumptions[1]

Recent experience has clearly shown how hard it is to predict future patterns of energy production and consumption. Projections of energy production in 2000 made during the past decade have ranged from under 100 quads to almost 200 quads. Figure 14-1 presents a number of different projections made in the 1970s. The figure suggests the need to be humble about our forecasting efforts, and underlines the wisdom of using several different scenarios to represent a variety of possible energy futures.

Briefly, the High Growth and Low Growth scenarios assume that total energy supply would expand at an average 2.1 percent per year under the High Growth, and at 1.5 percent per year in the Low Growth Scenario. In both, most of this growth would result from burning more coal, increasing nuclear-powered electricity generation, and recovering oil from Western oil shales. Table 14-1 summarizes SEAS scenarios assumptions for energy supply.

Under High Growth Scenario assumptions, use of coal is projected to rise from 22 percent of the total 1975 energy supply to 35 percent in 2000. A slower rate of increase in coal use is assumed in the Low Growth Scenario, in which coal would provide about 30 percent of the energy supply by 2000.

Nuclear energy production would grow by a factor of 7 in the High Growth Scenario, and 6 in the Low Growth Scenario. These projected sharp increases are consistent with actual growth in nuclear production since 1975, but, in the aftermath of the Three-Mile Island accident, may be too high (see Appendix B).[2]

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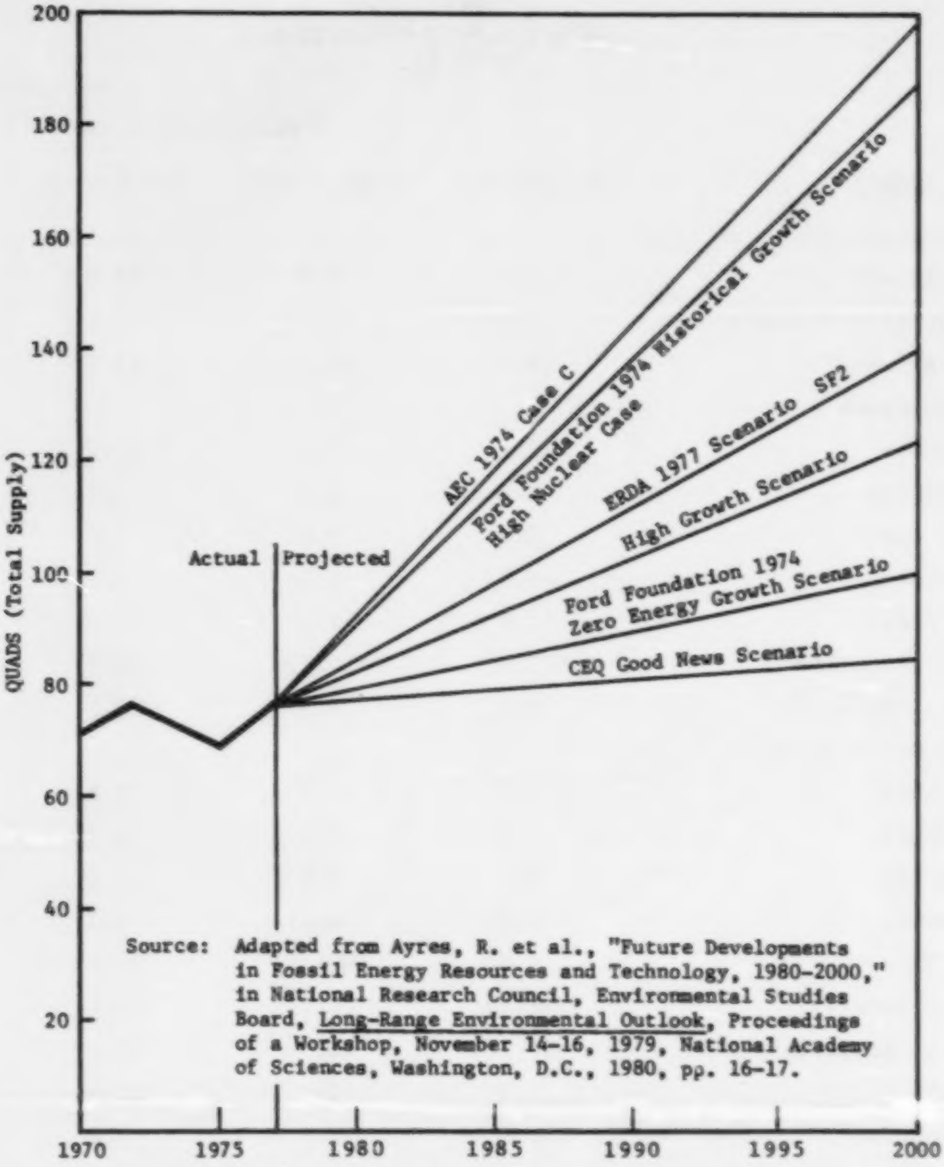
[1] The purpose of these scenarios is to frame the analysis, not to predict the future. For purposes of this analysis, the energy mix in the SEAS analysis is assumed. The distinction between what is assumed in the scenarios (e.g., penetration of alternative technologies) and what is projected based on these assumptions (e.g., resulting levels of conventional fuels production) is difficult to sort out. In this report we assume levels of energy production and project residuals generation associated with these levels of production.

[2] These projections also appear to be higher, based on the current rate of new plant orders over the past three years.



Source: Adapted from Ayres, R. et al., "Future Developments in Fossil Energy Resources and Technology, 1980-2000," in National Research Council, Environmental Studies Board, Long-Range Environmental Outlook, Proceedings of a Workshop, November 14-16, 1979, National Academy of Sciences, Washington, D.C., 1980, pp. 16-17.

FIGURE 14-1
SELECTED FORECASTS OF FUTURE ENERGY PRODUCTION

TABLE 14-1
ENERGY SUPPLY ASSUMPTIONS
(10^{15} Btu)

Energy Supply	1975 Supply	Supply in 2000 High Growth	Supply in 2000 Low Growth
Coal Production			
Strip mining	8.5	20.7	17.0
Underground mining	7.6	23.3	15.7
Total coal[a]	16.1	44.0	32.7
Oil Production			
Onshore	17.1	13.4	13.4
Offshore	2.8	3.9	4.0
Oil shale	0.0	5.4	2.2
Alaskan	0.4	6.2	6.0
Total	33.0	42.1	35.0
(Oil imports)	(12.7)	(13.2)	(9.4)
Total domestic	20.3	28.9	25.6
Natural Gas Production			
Onshore	14.3	10.8	12.6
Offshore	4.1	3.1	3.2
Alaskan	0.1	2.9	2.2
Biomass	0.0	0.05	0.05
Total	19.5	18.1	20.8
(Gas imports)	(1.0)	(1.2)	(2.7)
Total domestic[a]	18.5	16.9	18.1
Nuclear[b]	1.8	13.2	10.6
Hydroelectric[b]	2.6	3.2	3.2
Other[c]	0.0	3.8	2.4
Energy Supply Total[a]	73	124	105

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[a] Rounding may create inconsistencies in addition.

[b] Calculated as electricity demand divided by 0.34, in order to express energy supply on a basis equivalent to fossil fuel supplies. Actual nuclear output, for example, is 0.34 times the listed supply estimates.

[c] Supply of fossil fuels displaced by solar, geothermal, and biomass (electric) sources.

Figures on oil imports differ considerably between scenarios. The high world oil price assumed in the Low Growth Scenario is projected to stimulate domestic oil production, so that imports of oil decrease from 12.7 quads[3] in 1975 to 9.4 quads in 2000. Oil prices are assumed to rise less sharply in the High Growth Scenario; this lower cost of energy is expected to stimulate the general economy and lead to increases in consumption of both domestic and imported oil. Imports in the High Growth Scenario would increase from 12.7 quads in 1975 to 13.2 quads in 2000, while domestic production would rise from 20.3 quads to 28.9 quads (including oil shale).

New energy technologies play significant roles in both scenarios. Shale oil production would increase most sharply in the High Growth Scenario, in response to strong petroleum demand. This scenario assumes annual production of more than 5 quads of shale oil by 2000, representing the output of about 50 commercial-scale conversion plants. Solar, geothermal, and biomass sources would provide about 3 percent of the total energy supply in 2000 in the High Growth Scenario, and about 1 percent in the Low Growth Scenario.[4]

Energy use by transportation, residential, commercial, industrial, and export activities is diagramed in Figure 14-2. Overall, the demand for energy by these activities would rise in the High Growth Scenario by 70 percent between 1975 and 2000, from about 50 quads to 85 quads per year. The corresponding increase in the Low Growth Scenario would be about 33 percent, rising to a demand of 70 quads in 2000.

The residential and commercial uses of energy are similar in both scenarios. The most significant differences between the two scenarios regarding energy demand occur in the transportation and industrial fields because conservation potential is greatest in those activities, and their energy demands are most sensitive to changes in economic growth.

In transportation, the demand for energy in 2000 is projected to be 23 quads in the High Growth Scenario and 16 quads in the Low Growth Scenario. This large difference can be attributed to two factors: (1) a lower growth rate in gross national product (GNP) and population in the Low Growth Scenario, which would result in reduced demand for transportation; and (2) a shift toward mass transit

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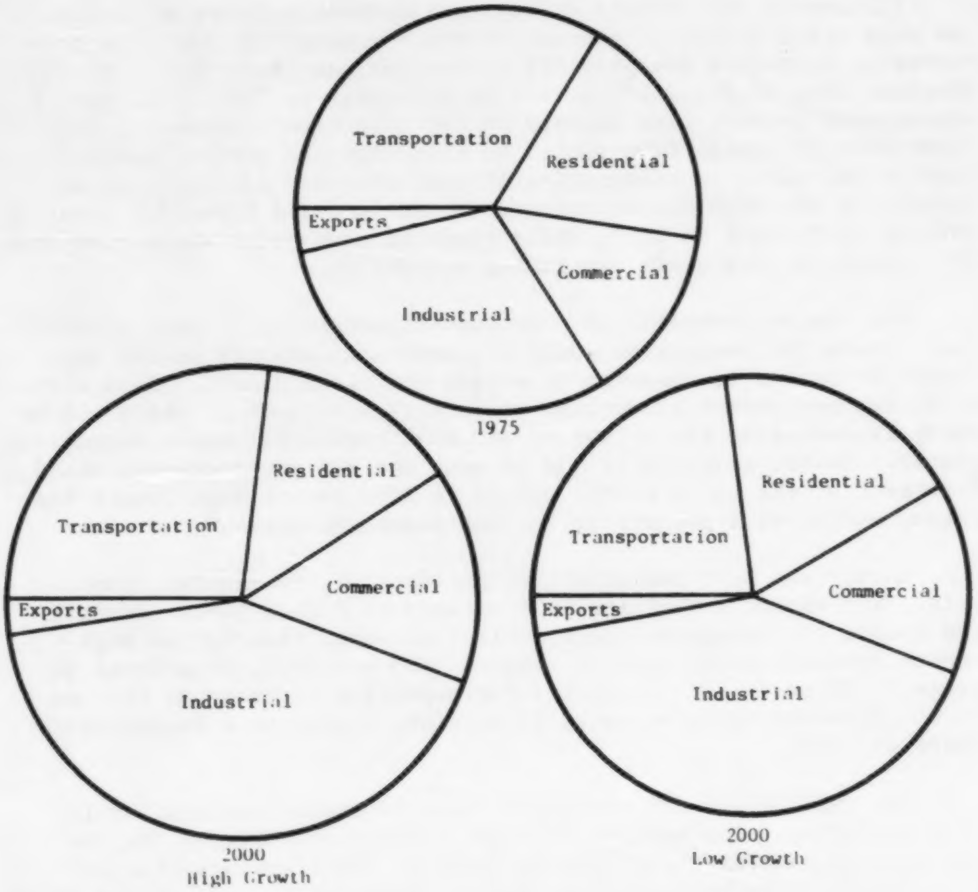
[3] One quad = 1 quadrillion Btu; 1 quad is the energy equivalent of approximately 170 million barrels of crude oil.

[4] Some of the implications of an energy "future" that includes more energy from solar, higher conservation, and other "soft path" sources are discussed in Section 14.3.3.



	1975		2000			
			High Growth Scenario		Low Growth Scenario	
	10^{15} Btu	Percent of Total	10^{15} Btu	Percent of Total	10^{15} Btu	Percent of Total
Transportation	18	34	23	27	16	23
Residential	10	19	12	14	13	18
Commercial	7	14	13	15	11	15
Industrial[a]	16	30	35	42	29	41
Exports	2	3	2	3	2	3
Total[b]	53	100	85	100	70	100

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[a] Includes demand for oil and natural gas as chemical feedstocks.

[b] Rounding may create inconsistencies in addition.

FIGURE 14-2
MAJOR ENERGY DEMAND ASSUMPTIONS

in urban areas in reaction to high oil prices. In the Low Growth Scenario, over 40 percent of all passenger miles traveled would be provided by mass transit in 2000, compared with 12 percent in the High Growth Scenario. In both scenarios, the projected average automobile miles per gallon reaches 27.5 in 2000 for all vehicles on the road.[5]

In evaluating the environmental implications of these energy supply and demand scenarios, a regulatory background for emission standards must also be established. The trend projections presented in this chapter make two simplifying assumptions: (1) that no additions or changes will be made to the standards promulgated as of July 1, 1978,[6] and (2) that all sources will attain full, on-time compliance with these standards. The effect of these assumptions may be to understate potentially significant emission levels wherever noncompliance problems are expected to be acute (e.g., mobile source controls) and overstate pollution problems in areas where future regulatory initiatives are anticipated (e.g., controls on combustion-related NO_x emissions, controls on heavy trucks and buses). This should be kept in mind when the results in this chapter are interpreted.

In addition to the analysis of the energy-related environmental trends projected for the High Growth Scenario and the Low Growth Scenario, the probable pollution impacts of several other possible "energy futures" are examined in this chapter. These alternatives call for:

- High Conservation
- High Solar
- High Synfuels
- Low Nuclear

Each of these scenarios is based on the assumption that national policy is directed toward encouraging or discouraging some form of energy use. Unlike the SEAS scenarios, the alternative energy futures examined are not based upon a detailed set of assumptions and an extensive data base. Consequently, these scenarios are examined qualitatively and their probable environmental trends are compared to those projected for the High Growth Scenario. Through these comparisons we can focus on how differing energy technology mixes might affect the major energy-related environmental impacts expected under the High Growth conditions.

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[5] Considering recently discovered problems in estimating fleet miles per gallon, it is uncertain whether actual fleet miles per gallon will attain 27.5 in the time period assumed, even though estimated fleet miles per gallon may well reach that mark.

[6] Revised New Source Performance Standards for utility boilers were promulgated in June, 1979. Current expectations are that similar standards will be promulgated for industrial boilers in 1981.

14.1.2 Regulatory Background

In the past three years, five major environmental laws which influence the ways energy is produced and consumed have been enacted or amended significantly:

- The Clean Air Act as amended in 1977 (PL 95-95)
- The Clean Water Act of 1977 (PL 95-217)
- The Resource Conservation and Recovery Act of 1976 (PL 94-580)
- The Toxic Substances Control Act of 1976 (PL 94-469)
- The Surface Mining Control and Reclamation Act of 1977 (PL 95-87)

A synopsis of the first four of these laws is presented in Section 3.4. The Surface Mining Control and Reclamation Act is discussed in Section 10.4. The Clean Air Act Amendments, the Resource Conservation and Recovery Act, and the Surface Mining Control and Reclamation Act have the most significant impact on energy production and use.

Recent energy-related legislation also has environmental implications. The Energy Supply and Environmental Coordination Act of 1974 (PL 93-319) and the Power Plant and Industrial Fuel Use Act of 1978 (PL 95-620) stipulate that coal replace oil and natural gas as fuel in new electric utilities and large industrial boilers. By virtually eliminating oil and gas as fuels for generating electricty in the future, these laws call for increased reliance on coal and uranium to produce electricity. The fuel mix assumptions for electric utilities are shown in Table 14-2.

The increased use of coal as fuel is of particular environmental significance because coal per unit of energy output creates more pollutants than either oil or gas. The New Source Performance Standards (NSPS) requirements of the Clean Air Act Amendments require that

TABLE 14-2
FUEL MIX ASSUMPTIONS FOR ELECTRIC UTILITIES
(10^{15} Btu)

Fuel Type	1975 Demand	Demand in 2000 High Growth	Demand in 2000 Low Growth
Coal			
Old[a]	2.9	2.3	2.6
New[b]	0.0	6.0	4.4
Total	2.9	8.2	6.9
Oil	1.0	0.5	0.8
Gas	1.0	0.05	0.6
Nuclear	0.6	4.5	3.6
Hydroelectric	0.9	1.1	1.1
Other	0.0	0.4	0.3
Total	6.4	14.9	13.3

[a] Pre-1976 plants, controlled by State Implementation Plan (SIP) regulations. The 1970 Clean Air Act Amendments set emission standards for plants constructed or modified after 1971; in the SEAS model, it is assumed construction of a plant requires four years. Therefore, plants beginning operation before 1976 and controlled under SIP regulations are termed "old."

[b] Post-1976 plants, controlled by New Source Performance Standards.

emissions from new coal-fired plants be stringently controlled. However, even with such controls, these existing, unmodified coal-fired plants not covered by NSPS requirements represent a significant source of pollutants, particularly sulfur and nitrogen oxides, through 2000.

14.1.3 Data Sources and Quality

The trends discussed in this chapter are generally derived from the SEAS-based portions of Chapters 4 (Air Pollutants), 6 (Water Pollutants), and 10 (Solid and Hazardous Wastes). A discussion of the sources and quality of the data used in developing these trends can be found in the appropriate sections of these chapters.

14.1.4 Chapter Organization

This chapter examines the trends for pollutants and water consumption associated with energy production and consumption. Section 14.2 summarizes the energy-related trends associated with both the High and the Low Growth Scenarios and points up contrasts between them, and then discusses implications of the major environmental issues posed by these pollutant trends. Section 14.3 describes the ways in which these issues would be affected by varying energy mixes and discusses the energy technologies and technology mixes that are environmentally the most damaging and the most benign. Section 14.4 summarizes the conclusions drawn from the analyses and comparisons.

The focus of this chapter is on national trends; however, some regional trends information is included. Following a description of pollution trends associated with the energy mix postulated in the High Growth Scenario, High and Low Growth trends are compared, and their implications are discussed.[7]

14.2 TRENDS IN ENVIRONMENTAL POLLUTANTS

The processing and combustion of fuels for energy--particularly the combustion of fossil fuels--are significant contributors to the atmospheric release of each of the criteria air pollutants, the effluent discharge of dissolved solids and oils and greases, and the generation of noncombustible solid wastes and industrial sludges.

This section examines the major energy-related pollution trends for air, water, and solid waste, as projected on the basis of SEAS High Growth Scenario assumptions. Many other pollution problems are associated with energy-related activities, including mine runoff, groundwater contamination, and land degradation. These problems, not analyzed in this year's Environmental Outlook, will be included in the future.

14.2.1 SEAS High Growth Scenario Pollution Trends

Air Pollution

In 1975, energy-related activities[8] accounted for more than half the net emissions of four of the five criteria air pollutants examined here. These percentages are:

Pollutant	Percent of Net Emissions
Total suspended particulates (TSP)	32
Sulfur oxides (SO_x)	87
Nitrogen oxides (NO_x)	80
Hydrocarbons (HC)	66
Carbon monoxide (CO)	90

Trends in energy-related emissions usually mirror the projected overall trend for total air pollutant releases from all sources between 1975 and 2000 in the High Growth Scenario. However, the kinds of contributions made by energy-related emissions to overall pollutant levels for the criteria air pollutants differ somewhat from pollutant to pollutant. In general, energy-related emissions fall into three broad categories;

(1) For particulates and sulfur oxides, most energy-related emissions are produced by the combustion of fossil fuels (primarily coal) in stationary sources such as electric utilities and industrial boilers. This pattern is expected to continue from 1975 to 2000.

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[7] There is considerable margin for error in estimating the residuals generated by production processes (e.g., sampling error, errors in estimating production levels, errors in facility siting, etc.). SEAS does not provide a framework for accounting for these errors. To aid in minimizing the biases introduced by some of these errors, two contrasting scenarios are analyzed in an attempt to "bound" the error.

[8] Energy related activities are defined as those activities concerned with the production, conversion, and consumption of energy. For example: the industrial combustion of coke to provide heat in steel production is an energy related activity while the production of steel by use of an electric arc furnace is not.

(2) For nitrogen oxides, the sources of 1975 energy-related emissions were almost equally divided between stationary source combustion of fuel and emissions from transportation sources. However, projections for increased coal use between 1975 and 2000, coupled with expected improvements in energy efficiency and the assumed implementation of emissions controls for transportation, would shift the bulk of future NO_x emissions to stationary-source combustion.

(3) Energy-related hydrocarbon and carbon monoxide emissions come primarily from fuels used in transportation, although petroleum refining would account for an increasing percentage of energy-related releases of hydrocarbons between 1975 and 2000.

Particulates. Nationwide, net particulate emissions from all sources are projected to decrease between 1975 and 2000[9]; the lowest point (roughly 45 percent below 1975 levels) is forecast as 1985, the year in which full compliance with State Implementation Plan (SIP) standards is assumed. After 1985, the effects of economic growth and increasing fossil fuel combustion are expected to reverse the overall downward trend. Net particulate emissions by 2000 are forecast to be only 15 percent lower than in 1975.

Coal combustion from all sources accounted for 30 percent of all particulates emitted in 1975. Particulate emission levels from coal combustion in 2000 are projected to be about 60 percent below 1975 levels. This decrease is expected even though a 250 percent increase in coal combustion is projected between 1975 and 2000. Compliance with SIP regulations, retirement of older, "dirty" plants, and stringent control requirements for new coal-fired plants, are expected to result in a sharper decline in particulate emissions from coal combustion than from non-energy-related sources.

Sulfur Oxides. Given the environmental policy assumptions contained in the High Growth Scenario, net emissions of sulfur oxides are projected to decrease by 9 percent by 1985, a drop attributable to compliance with SIP regulations. The level of sulfur oxide emissions is projected to remain relatively constant after 1985, but the effects of economic growth are expected to cause total net emissions to increase gradually. Total net emissions in 2000 are projected to exceed 1975 levels by only 6 percent.

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[9] These projections assume that old coal-fired utilities retire more slowly under Low Growth Scenario conditions. This assumption has been disputed. For a discussion of retirement rates, see Appendix B.

Emissions from utilities are projected to remain the single largest source of SO_x through 2000. However, the use of control technologies required by SIP, NSPS, and BACT standards is expected to lead to a decrease of almost 20 percent in net SO_x emissions from utilities between 1975 and 1985. Under High Growth assumptions, net emissions from utilities are forecast to remain fairly constant between 1985 and 2000, as the retirement of comparatively dirty, old (pre-1976) coal- and oil-fired plants counterbalances emission increases from additions of new coal-burning capacity.[10]

On the other hand, SO_x emissions from industrial combustion activity are expected to increase between 1975 and 2000, even with the use of emission control technologies. This is due to the projected large increase in industrial coal use. During this time period, industrial use of coal is projected to increase five times, while net emissions triple. This tripling of net emissions from industrial sources is projected to offset reductions from utilities and accounts for the slight increase seen in overall SO_x emissions between 1975 and 2000.

Nitrogen Oxides. While most nitrogen oxide emissions result from stationary-source fuel combustion, transportation is also a major source. Electric utility and industrial fuel use accounted for roughly 40 percent of NO_x emissions in 1975, while transportation sources represented 35 percent of emission levels for that year. Petroleum refining accounted for another 8 percent of national NO_x emissions in 1975. Unlike particulate and SO_x emissions, gross and net emissions of NO_x are virtually identical, because of the general absence of control requirements for most NO_x sources.[11]

Net NO_x releases are projected to increase by 20 percent between 1975 and 1985, as increases in fuel combustion residuals outweigh the anticipated emission decreases resulting from mobile source controls. Between 1985 and 1990, emission levels remain relatively constant as mobile source controls in the automobile fleet counterbalances the growth in industrial and utility fuel combustion anticipated in that time period. Emissions are expected to rise steadily between 1990 and 2000 as fuel combustion activity continues to increase and transportation-related emissions also begin to increase.

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[10] See Appendix B for a discussion of the environmental policy assumptions contained in the SEAS scenarios. The reader should keep in mind that this analysis assumes that all standards, including SIP standards, will be complied with in full in the future. Given the current trends on compliance with SIP standards, the validity of this assumption is questionable.

[11] Boiler modifications can reduce NO_x emissions from 5 to 50 percent. Requirements for modifications were not integrated into the version of SEAS used to produce this report.

Marked shifts in the relative importance of the major sources of net NO_x are anticipated for 2000. Extensive use of coal and oil instead of natural gas as an industrial boiler fuel (chiefly small boilers) would result in a nearly two-fold increase in combustion-related pollutants over the 1975 to 2000 time period. Emissions of NO_x from industrial fuel combustion by 2000 are projected to triple, while emissions from transportation sources would be expected to decline by roughly 25 percent from 1975 levels if currently promulgated mobile source standards are met.[12] Throughout the 25-year period, electric utilities are expected to increase net NO_x emissions by a factor of about 1.5. Electric utilities would continue to be the largest single source of NO_x emissions.

Hydrocarbons. In 1975, transportation was the primary source of net hydrocarbon (HC) emissions, accounting for 55 percent of the national total. Petroleum refining accounted for another 10 percent that year. The substantial reductions in net hydrocarbon releases projected for the 1975 to 2000 period are attributable to pollution control measures and technological improvements to autos and trucks.[13]

Net HC releases are projected to decline substantially between 1975 and 1985 and remain relatively constant thereafter. Much of the initial decline is due to reduced transportation emissions, reflecting the impact of compliance with present mobile source abatement requirements. Over the 1985 to 2000 time period, improvements in emissions controls are expected to be extended to all automobiles and result in further reductions in HC emissions.

The only significant source of HC projected to generate increased pollutants throughout the forecast period is petroleum refining and storage, in which only minor improvements in abatement practices are expected. However, even for this activity the expected shift toward the use of coal rather than liquid hydrocarbon fuels is projected to dampen emissions growth.

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[12] The extent to which these standards will actually be met is problematic, particularly considering recent experiences with catalyst poisonings due to the use of leaded fuels.

[13] This analysis assumes that pollution control requirements for auto and truck emissions will be met. These requirements are more stringent than those for trucks so that the decline in auto emissions is expected to offset the increase in truck emissions.

Carbon Monoxide.[14] In 1975, automobiles and trucks accounted for 90 percent of all net carbon monoxide emissions. Emission levels are expected to decline by approximately one-half between 1975 and 1990 and then level off. It appears that CO emission levels in the future will be determined largely by growth in transportation activities. Carbon monoxide emissions from automobiles in 2000 are expected to be only 30 percent of 1975 levels, and from trucks, only 68 percent. These decreases due to control requirements specified in the Clean Air Act would more than offset projected increases in nonenergy emission levels. Total CO emissions in 2000 are expected to be 55 percent of 1975 levels.

Water Pollution

The energy technologies included in our definition of energy-related activities would not directly contribute significantly to most of the point source water pollutants discussed in this report. However, there are two notable exceptions: total dissolved solids, and oils and greases.

Many energy technologies, particularly coal combustion technologies, may contribute significantly to water quality problems indirectly. By emitting quantities of sulfur oxides and nitrogen oxides into the atmosphere, coal combustion sources may be contributing to the lowering of pH in many lakes (see Chapter 5). Further, emissions of trace metals, in particular heavy metals, to the atmosphere may add to the concentration of these metals in water bodies.

Dissolved Solids. In 1975, electric utilities accounted for roughly one-half of all point source discharges of dissolved solids,[15] and they are projected to remain the major source of dissolved solids between 1975 and 2000. Net discharges are expected to increase by 175 percent during this time period, and by 2000, electric utilities are expected to contribute two-thirds of the point source dissolved solids discharge.

Increased discharges are attributable both to continued growth in electric generating capacity and to changes in the composition of this capacity. Output of electricity is expected to increase by 60 percent between 1975 and 2000, and gross discharges of dissolved solids can, therefore, be expected to rise at similar rates. In addition, this growth in discharges would be accelerated by the anticipated expansion of nuclear power. Substantial growth in nuclear generation of electricity (from 0.6 quads in 1975 to 4.5 quads in 2000) is expected to produce a ninefold increase in net dissolved solids discharges from nuclear power. Dissolved solids discharges from nuclear power plants are projected to increase at the same rate as nuclear output, since these emissions are not assumed to be controlled.

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[14] See footnote 13.

[15] Dissolved solids are a measure of the nonfilterable portion of total solids.

Oils and Greases. In 1975, 40 percent of the point discharges of oils and greases in the United States came from petroleum refining and storage. By 2000, overall releases of oils and greases are projected to decline to 70 percent of 1975 totals, whereas discharges from petroleum refining and storage are expected to increase to 125 percent of their 1975 levels and to 70 percent of the overall national total.

Water Consumption

In 1975, electric utilities accounted for one-half the water consumed by the energy and manufacturing industries. Since both the utility industry, as well as all energy and manufacturing industries combined are expected to double their water consumption by 2000, electric utilities are projected to maintain approximately the same share (one-half) of water consumption through 2000. This increased water consumption is attributable to the high growth rates projected for nuclear power plant generation and to the fact that these power plants consume almost two-and-one-half times as much water per kilowatt-hour generated as do conventional fossil fuel power plants.

The consumption of water during production of synthetic fuels from coal, particularly synthetic gas, is projected to increase from zero in 1975 to about 840 thousand acre-feet by 2000. Although this represents only about 7 percent of the total industrial water consumption projected for 2000, it is anticipated that many coal-based synthetic fuel plants will be located in the water-short areas west of the Mississippi River (Colorado, Montana, North Dakota, and Wyoming)[16] where the impacts of this consumption may be significant.

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[16] See White, I.L. et al., Energy From the West: Policy Analysis Report, U.S. Environmental Protection Agency, Office of Energy, Minerals, and Industry, Washington, D.C., 1979.

Solid Waste

Noncombustible Solid Wastes.[17] In 1975, coal-fired electric utilities accounted for over half the noncombustible solid waste (NCSW) produced in this country. Between 1975 and 2000, most NCSW is expected to come from removal of particulates and bottom ash from coal-fired utilities. The assumed rise in coal use, plus increasingly stringent requirements for particulate removal, leads to projections of higher annual NCSW from coal-fired electric utilities, with levels in 2000 expected to increase by 150 percent over 1975.

The generation of electricity by coal-fired power plants is expected to increase somewhat more rapidly than its associated solid waste: by 2000, coal-fired electricity generation is projected to increase by 183 percent over 1975 levels. The resulting decline in the generation of NCSW from coal-fired power plants relative to amount of electricity generated is due, in part, to the assumption that a growing portion of the coal used in power plants will be either cleaned coal or certain cleaner Western coals.

Industrial Sludges. Energy-related sources accounted for less than 1 percent of industrial sludges in 1975, but this picture is expected to change dramatically by 2000 when a tenfold increase in generation is projected. The major cause of the increase would be the imposition of stringent requirements--SIP, NSPS, and Best Available Control Technology (BACT) regulations--for the control of sulfur oxides on coal-burning power plants and industrial combustion facilities. These coal combustion sources are projected to generate roughly 70 percent of all industrial sludges by 1985 and 80 percent of all sludges by 2000. Coal combustion sources alone are projected to produce more than twice as much sludge annually by 1985 as did all sources in 1975.

Oil Shale Wastes. By utilizing the oil shale reserves within the Mountain Region (Federal Region VIII), oil shale production is projected to increase from zero in 1975 to 0.9 quads in 1985, 2.1 quads in 1990, and 5.4 quads in 2000. These levels of production are higher than those contained in the President's energy program. An increasing portion of this energy is assumed to come from in-situ oil shale techniques: 11 percent in 1985, 15 percent in 1990, and 20 percent in 2000. In-situ techniques result in much lower volumes of NCSW per Btu of energy produced in comparison with conventional recovery techniques. Nevertheless, annual generation of oil shale waste is projected to reach almost 1.5 billion tons by 2000 if oil shale production is pursued this vigorously.

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[17] Noncombustible solid waste is defined as the waste generated by the removal of particulates, ash, and dust in combustion and production processes (see Section 10.5).

Regional Trends

Air Pollution. Under High Growth Scenario conditions, most trends in the Federal Regions tend to mirror the national trends for air pollutants. However, several important exceptions emerge, particularly for electric utilities. The South Central Region (Federal Region VI) is the only region in which particulate levels from energy sources are expected to increase between 1975 and 2000. The shift in Federal Region VI from oil and gas utilities to coal-fired plants results in projected increases in particulate levels, but increases from such non-energy activities as the production of aluminum, stone, clay, and glass products are even greater.

Under the High Growth Scenario, the South Central and New England Regions (Federal Regions VI and I) show expected significant increases in sulfur oxide emissions due to energy production and use, chiefly from the introduction of coal-fired electric utilities into areas where little coal was used previously. In Federal Region VI, SO_x emissions are projected to more than triple between 1975 and 2000, primarily because of the "new" use of coal in electricity generation. Net SO_x emissions in Region I are projected to increase by nearly 20 percent between 1975 and 2000 as a result of converting some oil-fired plants to coal-fired capacity under the Energy Supply and Environmental Coordination Act (ESECA) and the construction of coal-fired plants in the region.

In all 10 Federal Regions, increased emissions of nitrogen oxides are projected, but large increases in net NO_x releases are anticipated in the Southeast, South Central, and Mountain Regions (Federal Regions IV, VI, and VIII). In these regions, coal use in utility and industrial applications is projected to expand very rapidly.

Regional trends for hydrocarbon and carbon monoxide generally reflect the national trend toward declining emissions between 1975 and 2000, given High Growth conditions. However, in certain areas, such as the Mountain, West, and Northwest Regions (Federal Regions VIII, IX, and X), where the petroleum refining industry is projected to grow, localized increases in HC emissions may be expected.

Water Pollution. The greatest relative regional increase in dissolved solids water pollutants is expected to be in the Northwest Region (Federal Region X), where annual net discharges are projected to increase 350 percent between 1975 and 2000, given High Growth conditions. This increase is primarily attributable to projected growth in coal-fired and nuclear utility generating capacity in the region.

Nuclear generation of electricity is considered responsible for an expected 160 percent increase in net dissolved solids discharged between 1975 and 2000 in the New England Region (Federal Region I). Projected increases in coal-fired and nuclear electrical output account for most of the rise in net dissolved solids discharges in the Southeast Region (Federal Region IV) over the 1975-2000 period, as this region experiences significant growth in electrical generation capacity.

Alaskan oil production is projected to increase more than tenfold between 1975 and 2000. The trans-Alaskan pipeline is expected to contribute significantly to increases in net discharges of oil and grease in the Northwest Region (Federal Region X). There will probably be more pipeline leaks and spills than is ordinarily the case because of environmental conditions unique to Alaska. Increased production of Alaskan oil can be expected to affect the net discharges of oils and greases from petroleum refining in the West Region (Federal Region IX). If, as assumed, a large portion of the oil from the Alaskan oil fields is refined in California, annual net discharges of oil and grease from petroleum refining and storage in the West would be expected to increase by 14 percent during the 1975-2000 period. However, reductions in oil and grease discharges due to compliance with effluent standards by non-energy industries would more than offset the increases from petroleum refining.

Water Consumption. Significant trends in energy-related water consumption are expected to occur in regions west of the Mississippi River. The Mountain Region (Federal Region VIII) is expected to exhibit the highest relative growth in water consumption for energy and manufacturing. Regional energy and manufacturing water consumption is expected to increase about thirteenfold between 1975 and 2000. Almost all the projected increases in Federal Region VIII are attributable to fairly water-intensive energy-related activities. These activities, which include oil shale mining, electric power generation, and synthetic fuel production, are expected to account for 90 percent of the regional increases in energy and manufacturing water consumption by 2000. Water use at the projected levels for manufacturing and energy would result in serious conflicts with domestic and agricultural uses.

The South Central Region (Federal Region VI) is also expected to exhibit major growth in energy-related water consumption. The principal energy-based water consumer in this region is expected to be the electric utilities industry throughout the 1975-2000 period. This industry's annual water consumption in 2000 is projected to be more than four times its 1975 level. Coal conversion activity is also expected to contribute to energy-related water consumption by 2000, totaling roughly 10 percent of industrial and energy water use by that time.

Solid Waste. Under the High Growth Scenario conditions, the South Central Region (Federal Region VI) is projected to show substantial increases in noncombustible solid wastes between 1975 and 2000. NCSW generation is projected to reach more than five times its 1975 levels by 2000, primarily because of rapidly increasing use of coal as fuel for electric power generation and as a substitute for natural gas in industrial combustion facilities. By 2000, Federal Region VI is expected to account for 23 percent of all conventional NCSW generated nationally.

However, by 2000, oil shale wastes are expected to account for nearly three times as much NCSW as all other NCSW sources combined. These wastes are expected to be exclusively located in the Mountain Region (Federal Region VIII), the site of the richest oil shale deposits in the nation.

In 1975, a major portion of industrial sludge was generated in four regions: Middle Atlantic, Southeast, Great Lakes, and South Central (Federal Regions III, IV, V, and VI). These regions are also projected to receive the major share of new coal combustion facilities; for this reason, overall sludge generation in these regions is expected to increase more rapidly than the national rate. Thus, these regions will continue to account for at least 70 percent of projected industrial sludge generation through 2000 under High Growth conditions.

14.2.2 Low Growth Scenario Comparisons

The High and Low Growth Scenarios postulate different growth rates for energy between 1975 and 2000. Total energy supply would expand at an annual average 2.1 percent under High Growth conditions, and 1.5 percent under Low Growth. This rise in the energy supply is attributed chiefly to more coal use, more electricity generation from nuclear power, and oil recovery from Western oil shales.

These differences in postulated rates of growth in energy supply result in different projected trends in environmental pollutants associated with energy production and consumption. In general, under Low Growth conditions, lower pollutant levels are expected. However, because differences in the GNP assumed for each scenario lead to different energy supply mixes, the differences in pollutant levels between scenarios are not simply proportional to the differences in the assumed rates of energy growth.

Differences in Coal Use

Under the High Growth Scenario assumptions, use of coal would rise from 22 percent of the total 1975 energy supply to 35 percent in

2000. In the Low Growth Scenario, slower increase in coal use is assumed: coal would provide about 30 percent of the energy supply by 2000. The higher use of coal by electric utilities and industrial boilers projected in the High Growth Scenario is reflected in the trends of several pollutants. For particulates, SO_x, and NO_x, national emission levels in 2000 are projected to be higher under the High Growth than under the Low Growth Scenario. And in those regions where a higher growth rate for new utility and industrial coal use is postulated, higher levels of particulates, SO_x, and NO_x are also projected.

However, in some regions, older plants continue to represent a substantial source of these pollutants until 2000. Since the SIP standards that apply to pre-1976 plants are less stringent than the controls placed on new facilities, older plants emit more pollutant per unit of electricity generated than do new plants. In the High Growth Scenario, for example, old coal-fired plants would generate 40 percent of the coal-fired electricity in 1985, yet they would produce 60 percent of the particulates from coal-fired plants. (See Appendix B, on boiler retirement rate.) Under Low Growth conditions, old plants are predicted to release even more particulates because slower retirement rates are assumed for these plants.[18] This is particularly significant in a region such as the Great Lakes (Federal Region V) where numerous coal plants were operating in 1975.

A similar trend is evident for solid waste generation, where High Growth Scenario levels in 2000 are expected to exceed those for the Low Growth case. As reflected at the regional level, the scenario in which coal use is expected to be higher (both for combustion and for production of synthetic fuels) is projected to have higher levels of NCSW and industrial sludges.

Note that the projected increases for industrial sludges and NCSW are tied to the assumptions made about environmental regulations and the pollution control equipment required to meet them. It is assumed that most new coal plants coming on line in the 1980s will be equipped with wet, nonregenerable scrubbers designed to meet NSPS and BACT requirements. However, this method of sulfur oxide control leads to large volumes of solid waste requiring proper disposal. Further, all plants coming on line after 1975 will have to meet the

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[18] Old coal-fired utilities produced more particulates in the Low Growth Scenarios since, due to the assumptions of slower retirement rates, there are more old plants in a given year after 1975 in the Low Growth than in the High Growth Scenario.

NSPS and BACT particulate emissions standards and hence generate large volumes of NCSW. Both these solid wastes will require proper disposal. Thus, the increased coal use assumed in both scenarios, coupled with the requirements of the Clean Air Act, is directly linked to the projected trends in solid waste generation.

Differences in Oil Use

One of the primary differences in High and Low Growth Scenario assumptions is in oil use, in particular oil imports. The price of oil between 1985 and 2000 is assumed to be 50 percent higher in the Low Growth Scenario than in the High. Under the Low Growth Scenario it is assumed that this high price would stimulate domestic oil production, and that imports of oil would decrease from 12.7 quads in 1975 to 9.4 quads in 2000. It is assumed that the lower cost of oil postulated in the High Growth Scenario would stimulate the general economy, and that consumption of both domestic and imported oil would increase. Imports under High Growth would increase from 12.7 quads in 1975 to 13.2 quads in 2000, while conventional domestic production (i.e., not including oil shale) would increase from 20.3 quads to 23.5 quads compared to 23.4 quads in the Low Growth Scenario. Thus projected conventional domestic production of oil is virtually identical in the two scenarios. The difference in projected oil totals stems primarily from the projected import rates and the assumptions on development of synthetic crude from oil shale.

Pollutants associated with oil use, emissions of hydrocarbons and discharges of oils and grease from refineries, are expected to be higher in the High Growth Scenario. These are of particular importance in regions where imported crude is refined. Because the two scenarios assume roughly the same amount of domestic crude oil production (including Alaskan oil), little difference is projected for releases from the conventional oil fuel cycle.

Differences in New Technologies

Oil shale technologies play a significant role in both scenarios. Shale oil production would increase most sharply in the High Growth Scenario, in response to strong petroleum demand and healthy economic conditions. The increase would be twice that anticipated under Low Growth conditions, despite the high world oil price assumed in the Low Growth scenario. Under High Growth conditions, oil shale wastes in the Mountain Region (Federal Region VIII) would also be twice as great.

Taken together, other new technologies would provide only about 1 percent of the U.S. energy supply in 2000 in either scenario.

Differences in Energy Demand

Between 1975 and 2000, the proportion of energy required for transportation would decline from 34 percent to 27 percent of all energy demand in the High Growth Scenario, and to 23 percent in the Low Growth Scenario. The actual amount of energy used in transportation would increase by about 25 percent in the High Growth Scenario but would decrease by 10 percent in the Low Growth case. Thus hydrocarbon and carbon monoxide levels, which decline sharply under High Growth assumptions due to compliance with existing regulations, would be even lower in the Low Growth case in 2000.

By far the greatest increase in energy demand would occur in industry, which would double its demand in both scenarios. This means that the energy used by industry would rise from 30 percent of all energy demand in 1975 to 40 percent in 2000. By 2000, in the High Growth Scenario, industrial demand for coal is 75 percent higher than in the Low Growth Scenario and industrial demand for oil is 50 percent higher. However, industrial demand for natural gas is 15 percent higher in the Low Growth Scenario. Industrial uses of coal and oil are much more polluting than industrial uses of natural gas--hence, the trend toward higher pollution levels assumed in the High Growth Scenario.

14.2.3 Implications of Environmental Trends Associated With the High Growth Scenario

The energy-related environmental trends discussed here highlight several important factors.

Sulfur oxides. Most areas not in compliance with ambient air quality standards for sulfur dioxide in 1975 were concentrated in the heavily industrialized Middle Atlantic and Great Lakes Regions (Federal Regions III and V), particularly along the Ohio River Valley. The high sulfur oxide emission levels in these Regions represented a health risk. They also contributed to acid rain problems in the New England and New York-New Jersey Regions (Federal Regions I and II) through the long-range transport of SO_x. Sulfur dioxide emissions are projected to decline slightly by 2000 from their 1975 levels in Federal Regions III and V, under High Growth assumptions; however, these Regions are still expected to have relatively high SO_x levels. It is not clear whether these declines would be large enough to improve eastern air quality significantly.

Air quality in other areas may be degraded by increased sulfur oxide emissions projected under High Growth assumptions. Coal use by industry and utilities is expected to increase substantially in the South Central Region (Federal Region VI). Because natural gas was a primary fuel in that Region, sulfur oxide levels were relatively low in 1975; sharply increased coal use is expected to cause large increases in SO_x levels by 2000. These increases may degrade air quality in heavily industrialized areas, particularly in Texas.

Similarly, substantial increases in SO_x emissions are expected by 2000 in the Mountain Region (Federal Region VIII). The principal sources are expected to be coal-fired utilities and industrial boilers, coal gasification and liquefaction plants, and oil shale facilities. However, SO_x emission levels in the Mountain Region are not expected to be as high as those in other regions. Meeting requirements for the protection of Class I Prevention of Significant Deterioration (PSD) areas[19] may affect energy production in the Region, primarily in terms of facility size and siting.

Nitrogen Oxides. Nitrogen oxide emissions increase substantially in the High Growth Scenario. While auto emission standards are expected to reduce NO_x emissions from transportation sources, greater reliance on coal is projected to lead to increases of NO_x in every Federal Region by 2000.[20] Because adequate abatement technologies do not currently exist to control these emissions (see Chapter 4), NO_x is already a major contributor to acid rain. As sulfur oxide emission levels decline, the composition of acid rain may become increasingly nitric. Continued increases in NO_x emission levels may also compound photochemical oxidant problems in many urban areas, including those that have made progress in smog cleanup through reductions in NO_x emissions from transportation sources.

Solid Wastes. The increased coal use and the environmental controls assumed in the High Growth Scenario would lead to large volumes of solid waste being generated annually by 2000. In comparison, oil and gas use results in relatively low solid waste levels. The high ash content of coal produces large volumes of bottom ash and fly ash after burning, and control devices required to meet NSPS and BACT regulations generate additional volumes of solid waste. The use of electrostatic precipitators and wet, nonregenerable scrubbers to remove particulates and sulfur dioxide from stack gases results in large amounts of ash and sludge that require handling and disposal. These wastes would have to be disposed of in compliance with the future regultions under the Resource Conservation and Recovery Act of 1976 (PL 94-580). This would affect the cost of using coal.

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[19] Mandatory Class I areas include land set aside as national parks, forests, etc. See Chapter 4.

[20] This projection assumes that no changes will be made to NO_x emission control requirements between 1978 and 2000.

Synthetic Fuels. Increased reliance on domestic coal and oil shale would place a heavy environmental burden on the Mountain Region (Federal Region VIII). The states of Federal Region VIII are rich in energy resources as well as natural beauty. However, the availability of water supplies that would be adequate for energy development is uncertain. Under High Growth Scenario assumptions, oil shale wastes would reach 1.5 billion tons annually by 2000, almost all of which would be in a small area of northwestern Colorado. The disposal of these wastes in environmentally acceptable ways is a challenge for which there is as yet no answer.

The Mountain Region (Federal Region VIII) is also a prime candidate for coal liquefaction and gasification development. These technologies result in substantial solid waste volumes, in addition to increasing demands on limited water supplies and affecting air quality. Coal-fired utilities locating near the vast coal seams would lead to even higher levels of air pollutant emissions than oil shale and coal conversion activities combined. In no other region do the goals of environmental quality and energy self-reliance clash so sharply.[21]

As previously discussed, the greater energy-related activity associated with the High Growth Scenario generally leads to projections of higher levels than those for the Low Growth Scenario, particularly because of the higher levels of coal use assumed under the High Growth Scenario. Despite stringent control requirements for new coal-fired utilities and large industrial boilers, more coal use leads to more air pollutant emissions and solid waste generation in both scenarios. Older plants, controlled by less stringent regulations, contribute a larger percentage of energy-related air pollutant emissions under Low Growth conditions because of the slower retirement rate for these plants. However, the high growth rate for coal use projected for the High Growth Scenario more than offsets this difference.

14.2.4 Implications of Scenario Differences

Despite projections of overall lower levels of sulfur oxide emissions by 2000 in the Low Growth Scenario (compared to those for the High Growth case), emission levels in the Middle Atlantic and Great Lakes Regions (Federal Regions III and V) are projected to remain high between 1975 and 2000 in both scenarios. Whether the projected small reduction in emission levels between the two scenarios would alleviate air quality problems in Federal Regions III and V and reduce acid rain levels in the New England and New York-New Jersey Regions (Federal Regions I and II) is uncertain, but some improvements would be expected both in comparison to 1975 conditions and projected High Growth trends.

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[21] Since the Mountain Region is so vast, direct comparisons on the Federal Region level are potentially misleading. The discharge of pollutants affects portions of the Region (e.g., the quality of a stream or the land used for waste disposal). The reader should keep in mind that to directly compare regional pollutant releases, the comparison should be done on a per unit of area (volume) affected, not on a per unit of area (volume) in the Region as a whole.

Nitrogen oxide levels under Low Growth conditions are expected to be lower than under High Growth in every Federal Region by 2000; nevertheless, emissions in all Federal Regions are expected to increase from 1975 levels. Thus, NO_x emissions will remain an environmental concern through 2000.

Solid waste generation levels are expected to be lower under the Low Growth conditions than under High Growth conditions because of lower levels of projected coal use. Also, slower depreciation rates assumed for old electric utilities and industrial boilers in the Low Growth Scenario would tend to slow further the growth rate of new, stringently controlled coal-fired utilities. With fewer plants using electrostatic precipitators and scrubbers, less sludge generation is projected under Low Growth conditions. Although NCSW and industrial sludge disposal requirements will be substantial under Low Growth assumptions they will be less severe than under High Growth assumptions.

Oil shale wastes by 2000, under Low Growth conditions, are expected to be roughly half those projected under High Growth. Even so, the solid waste generated annually by oil shale production is expected to be enormous by 2000. Thus, under Low Growth assumptions, spent shale disposal and reclamation problems would still be expected to occur in northwest Colorado well before 2000.

14.3 COMPARISON OF ENVIRONMENTAL ISSUES ASSOCIATED WITH DIFFERING ENERGY SCENARIOS

Future patterns in energy supply and demand will be influenced by many factors--the complex interactions of world oil prices, domestic economic conditions, technological development, and national energy and environmental policy. The SEAS High Growth and Low Growth Scenarios form a basis for examining only two of a wide range of possible "energy futures." A major national policy promoting rapid development of solar technologies or synthetic fuels could lead to vastly different future energy mixes and, as a result, significantly affect pollutant trends. Similarly, a moratorium on nuclear energy development or the adoption of an effective conservation policy would result in still other energy futures and different environmental pollutant trends.

This section examines environmental pollutant trends associated with several different energy futures and assesses the impact of varying energy mixes on the environmental issues identified in Section 14.2.

An energy technology's contribution to a pollution problem depends on both the amount of energy produced by the technology and the amount of pollutants generated per unit of energy produced. Detailed quantitative pollutant projections are not available for the alternative energy scenarios discussed here; hence, the discussion of their impact on projected environmental issues is primarily qualitative. However, a comparative assessment of the amount of a pollutant generated per unit of energy is useful in the analysis of the environmental "tradeoffs" represented by various energy futures.

14.3.1 Pollutant Releases from Energy Technologies

The projected amount of a pollutant produced by a source is estimated using projected production activity levels and a pollutant coefficient. A number of these coefficients have been used to calculate the quantities of pollutants in terms of tons per trillion Btu's produced, as illustrated in Figures 14-3 through 14-7. These coefficients are national averages for operation-related pollutants based on the pollutant generation and activity levels projected in the SEAS High Growth Scenario. Unlike the SEAS coefficients, these coefficients do not take into account regional differences in pollution generation, or changes in generation that might occur over time. However, they do provide a useful description of the direct environmental impacts of different energy initiatives.

It must be stressed that an assessment of the direct environmental impacts of energy initiatives presents only a portion of the picture. Further, this portion may be misleading as in the case of certain solar initiatives. However, an assessment of the indirect impacts related to increased levels of materials production by industry that may arise as a result of an energy initiative is a very complex procedure. A comprehensive assessment of this nature is beyond the scope of the current Environmental Outlook. In the following sections, the indirect impacts of energy initiatives will be addressed whenever possible.

The pollutant coefficients for the emissions of particulate matter to the atmosphere are presented in Figure 14-3. Because the ash content in coal is generally high, compared with other fuels, coal-fired utilities emit greater amounts of particulates per unit of

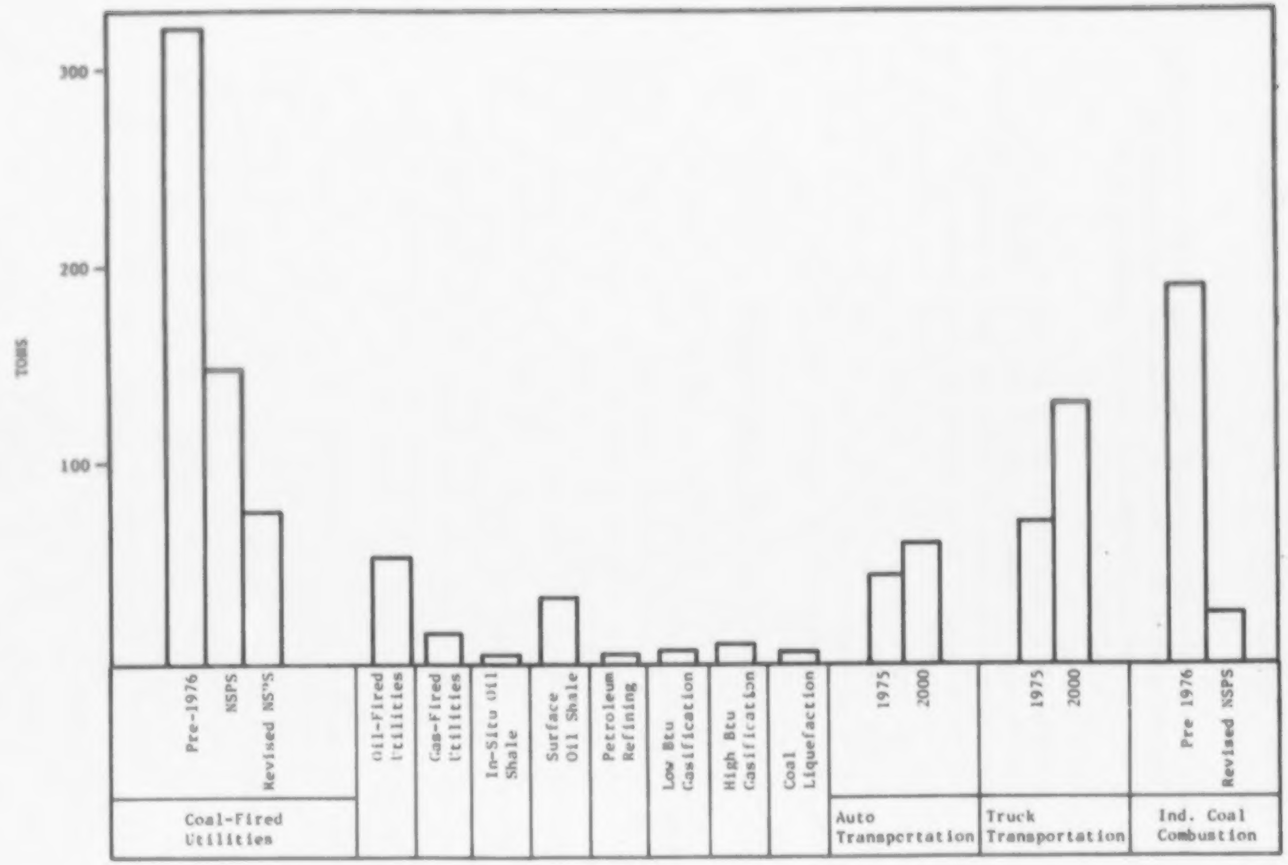

FIGURE 14-3
PARTICULATE (TSP) EMISSIONS
PER 10^{12} Btu PRODUCED

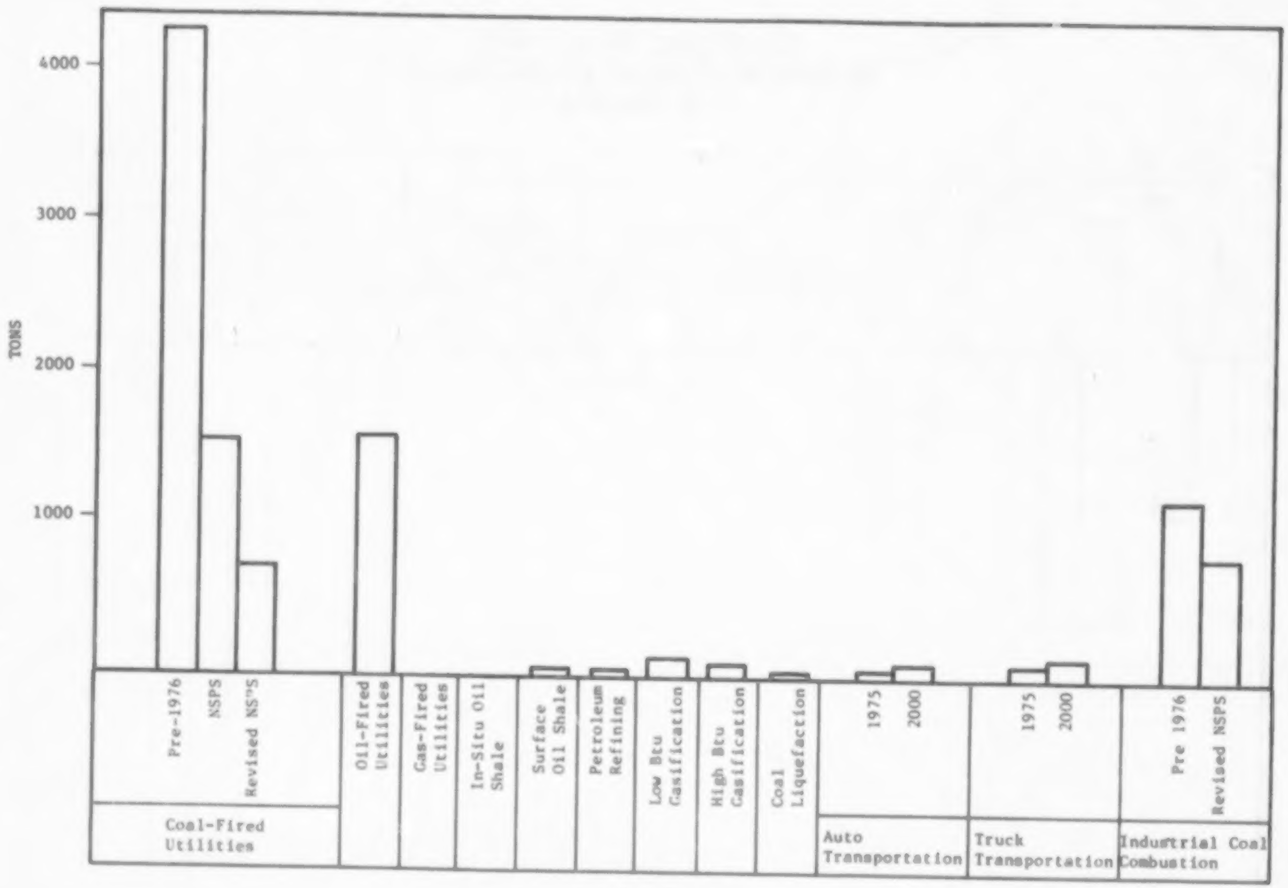

FIGURE 14-4
SULFUR OXIDE (SO_x) EMISSIONS
PER 10^{12} Btu PRODUCED

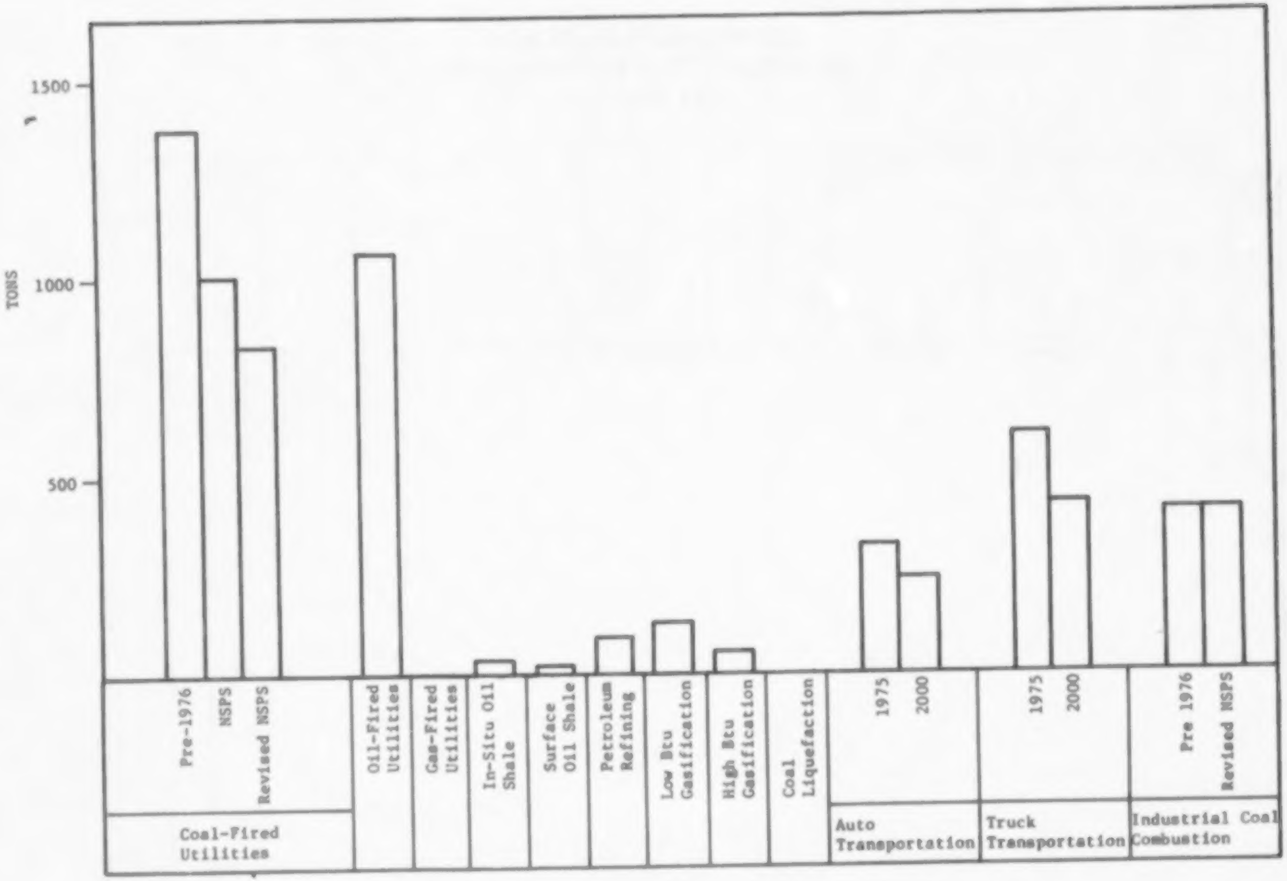

FIGURE 14-5
NITROGEN OXIDE (NO_x) EMISSIONS
PER 10^{12} Btu PRODUCED

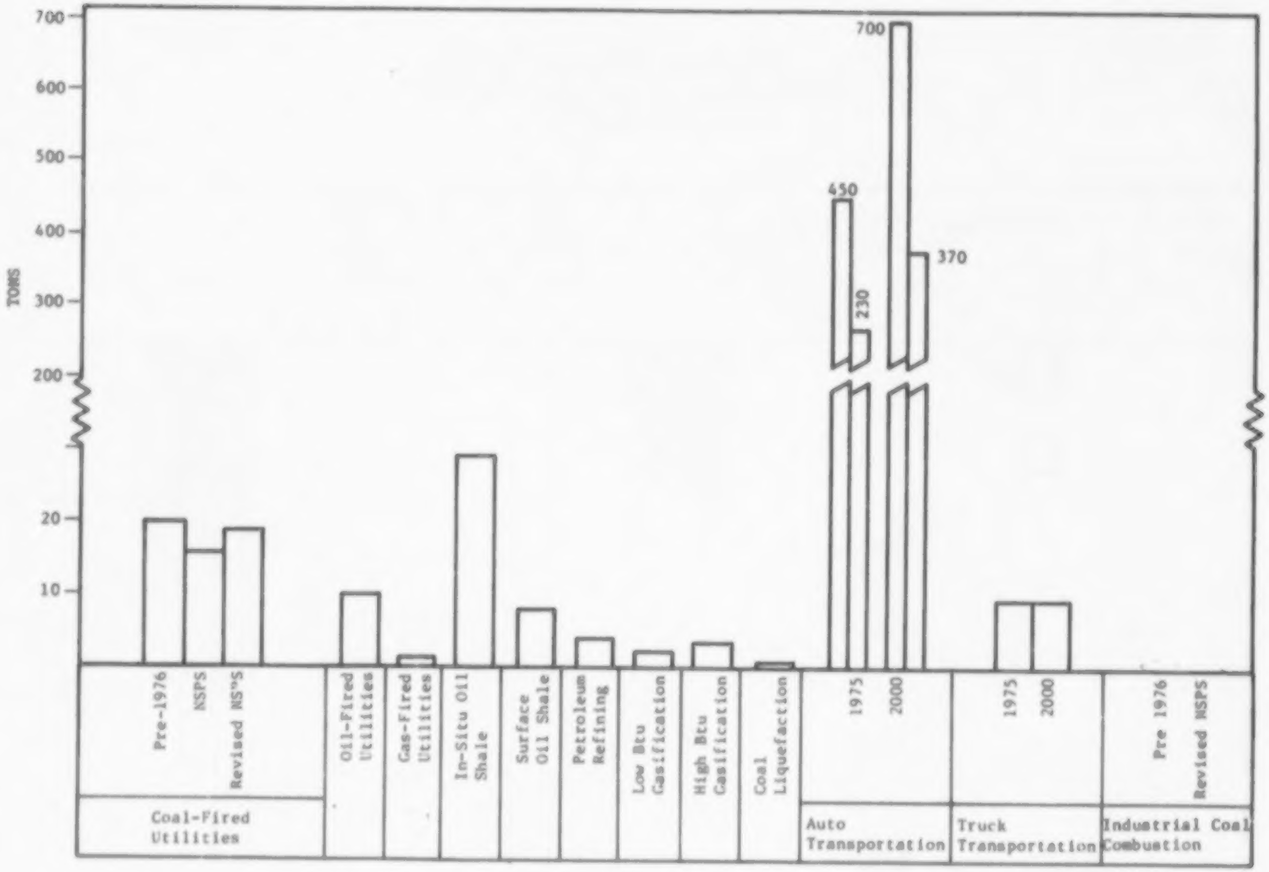

FIGURE 14-6
HYDROCARBON (HC) EMISSIONS
PER 10^{12} Btu PRODUCED

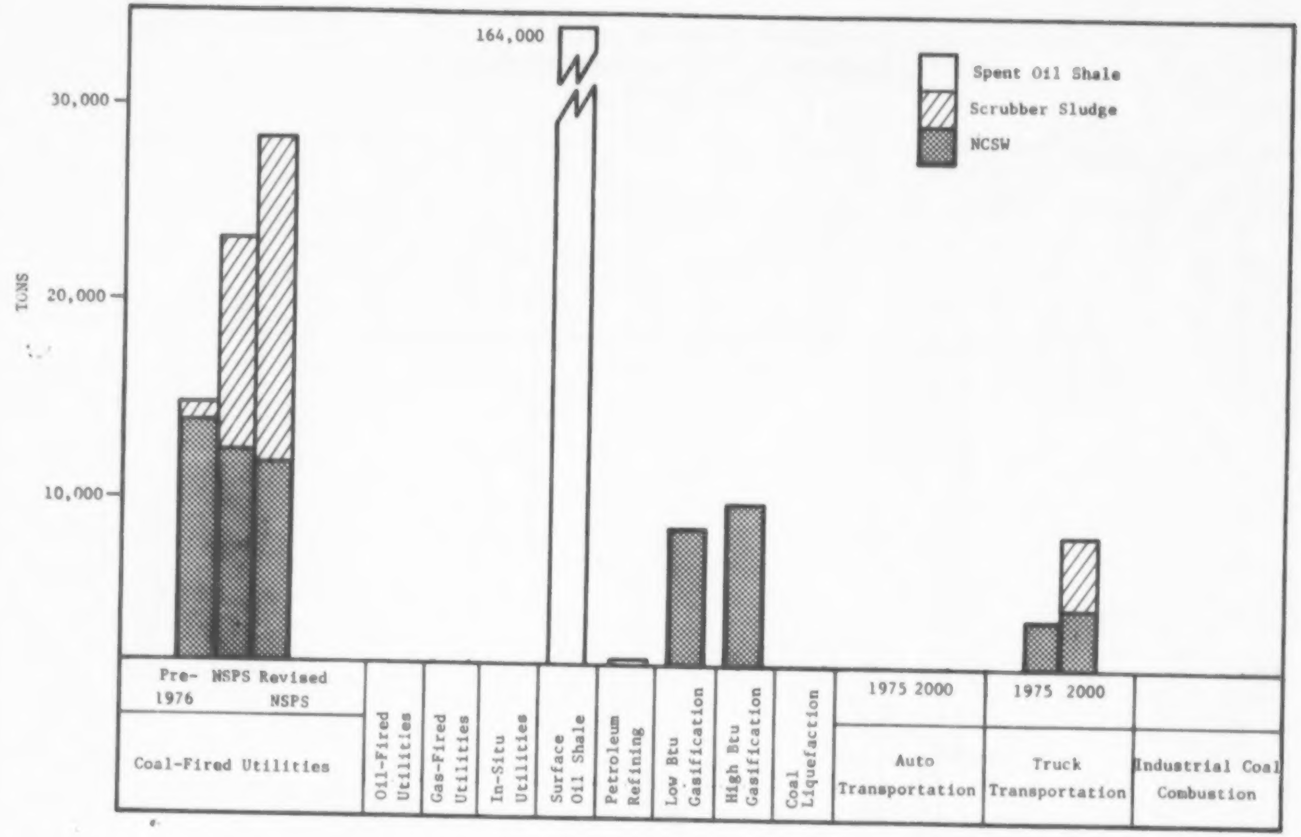

FIGURE 14-7
GENERATION OF SOLID WASTES
PER 10^{12} Btu PRODUCED

energy output than any other source, including both oil- and gas-fired utilities. A significant reduction in emissions is achieved, however, through the imposition of NSPS and revised NSPS requirements on coal-fired utilities. Truck transportation and industrial combustion are also significant potential sources of particulates.

The second major pollutant of concern for energy technologies is sulfur oxides. Coal-fired utilities are even more of a major source for SO_x emissions than for particulate emissions relative to other energy-related sources (Figure 14-4). Implementing NSPS and BACT requirements results in a marked decrease in SO_x emissions per unit of energy output. In the case of coal-fired utilities, BACT decreases the emissions per unit of heat input lower than those of industrial coal boilers under BACT requirements. New oil-fired utilities must also comply with these standards and will, therefore, exhibit similar declines in emissions of SO_x. Except for industrial coal combustion, none of the other sources studied is significant, compared to coal-and oil-fired utilities.

The pollutant coefficients for nitrogen oxides (NO_x) are presented in Figure 14-5. Pre-1976 coal-fired utilities emit significantly more NO_x per unit of output than any other source studied. NSPS and revised NSPS requirements result in decreased NO_x emissions for new coal-fired utilities. Comparable declines are expected for new oil and gas utilities.[22] In contrast to particulates and SO_x, these expected emission reductions result from anticipated future boiler modifications rather than the application of flue gas control devices. As a result, NO_x emissions in the United States are expected to increase in most high-coal-use scenarios. Aside from utilities, transportation sources are the only other major sources of those studied.

Transportation sources are the most significant contributors of hydrocarbon emissions on a per unit consumption basis[23] (Figure 14-6). Hydrocarbon emission rates decline markedly between 1975 and 2000. However, even after these decreases, the HC coefficients for transportation sources are still one order of magnitude higher than any of the other sources studied. The major sources, other than transportation, are oil shale retorting and electric utilities.

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[22] Oil- and gas-fired utilities constructed after 1984 must also comply with revised NSPS standards. The High Growth Scenario assumes no such plants will be built.

[23] Since transportation does not produce energy, unlike utilities, transportation pollutant coefficients are on a per unit consumption basis rather than a per unit production basis. Industrial coal combustion also is on a per unit consumption basis.

By far, the most significant source of solid waste on a per unit output basis is surface oil shale mining and retorting which generates approximately 164,000 tons of spent oil shale per trillion Btu produced. Coal mining is also a significant source of solid wastes, both in aggregate and on a per unit output basis.[24] Aside from these mining-related technologies, coal-fired utilities generate the most significant amount of solid wastes. These wastes consist of bottom ash, captured fly ash, and scrubber sludge. The generation of these wastes is directly related to the air pollution standards under which the plants operate, as shown in Figure 14-7. Both high- and low-Btu coal gasification technologies also generate significant quantities of solid waste on a per unit of energy output basis. This waste consists primarily of ash.

Again it must be stressed that the coefficients presented here represent the direct impacts of energy technologies only. The indirect effects, such as emissions from increased steel production associated with switching from oil imports to oil shale, may be more significant. These considerably more complex emission patterns are not directly examined in this report.

14.3.2 Major Energy-Related Pollutant Trends of the High Growth Scenario

In Section 14.2.4, four major energy-related environmental problems were identified and discussed for the High Growth Scenario by the year 2000:

- Continued high levels of sulfur oxide emissions
- Substantial growth in nitrogen oxide emission levels
- Enormous increases in solid waste generation
- Impacts associated with synthetic fuel production

Projected increases in the use of coal by utilities and industries are largely responsible for the first two problems identified, and they make a substantial contribution to the third. Not only are the production and use of synthetic fuels from oil shale projected to be major sources of solid wastes by 2000, but the likely concentration of these industries in the Mountain Region (Federal Region VIII) would place a heavy environmental burden on this relatively pristine area.

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[24] See Chapter 10, Section 10.4.

The Importance of Coal Use by Old Plants

As discussed earlier, existing energy legislation, notably the Power Plant and Industrial Fuel Use Act of 1978 and the Energy Supply and Environmental Coordination Act of 1974, limits the use of oil and gas in new energy facilities and requires switching from oil to coal in some older facilities. New electric utilities and large industrial boilers are to be prohibited from burning oil and gas. Thus, in utility installations, until solar and other renewable energy sources become viable, the choice of fuel is either coal or uranium.

The increased costs of burning coal in electric utilities, in conjunction with the enforcement of environmental regulations, are expected to prolong the operation of older oil and gas facilities (not affected by ESECA) and, more importantly from an environmental perspective, to prolong the use of older coal plants governed by less stringent environmental standards. The effects of this trend are clearly demonstrated by the sulfur oxide emissions projections in the High Growth Scenario. It is projected that by 2000, pre-1976 electric utilities would account for 32 percent of national SO_x emissions and 63 percent of SO_x emissions from all coal-fired utilities. This trend is even more pronounced under assumptions of the Low Growth Scenario, which assumes a lower rate of retirement for old coal plants; by 2000, pre-1976 electric utilities account for 40 percent of total national SO_x emissions and 68 percent of SO_x emissions from all coal-fired utilities.[25]

These projected trends underscore an important point in evaluating the sulfur oxide trends associated with alternative energy futures. Forecasts of increased solar use or increased conservation may reduce the demand for new coal-fired facilities in the United States, but they will not affect the operation of these older, more polluting plants. Thus in a region such as the Great Lakes (Federal Region V), where there are currently high SO_x emission levels from old coal-fired plants, a scenario assuming a different energy mix by 2000 probably would not have much impact on regional emissions levels. However, in a region such as the South Central (Federal Region VI), where a large increase in new coal-fired capacity is projected, displacement of these plants by other energy sources could greatly reduce projected increases in SO_x emissions.

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[25] The lack of a more clear-cut distinction in the contribution of old coal-fired plants in these two scenarios is related to the assumption of retirement rates. The differences in retirement rates assumed, though significant in the long term, are not quite as significant in the medium term.

Hence, if SO_x emissions are to be reduced substantially by 2000, especially in those regions which have high emission levels today, the retirement of these old plants would have to be accelerated or SIP standards tightened. Because older plants are cheaper to operate and because energy policy currently calls for expanded coal use, accelerated retirement of these plants is not likely to occur. Further, because the utilities converted from oil to coal under ESECA were made subject to SIP standards rather than the more stringent NSPS regulations, there is little indication that existing SIP regulations will be tightened in the near future.

Prolonged operation of old coal-fired utilities will result in a trend in projected NO_x emissions that is parallel to the SO_x trends. Only limited NO_x controls are assumed under NSPS standards, and NO_x emissions from plants under SIP regulations are assumed to be uncontrolled. Therefore, as with SO_x, old coal-fired utilities are more polluting per unit of energy produced than newer, more stringently controlled facilities.

Impacts of New Coal Plants

Because new coal-fired utilities would control sulfur oxide emissions in accordance with NSPS regulations, they would emit less SO_x to the air but create more sludge from flue gas desulfurization than older coal-fired plants. In addition, controlling particulates results in large volumes of ash, which also require disposal. Thus, with regard to solid waste, new coal-fired utilities can be expected to generate more pollutants than old coal-fired plants. Improper disposal of these wastes could cause leaching of toxic and hazardous substances into soils and ground and surface waters. However, strict compliance with future Resource Conservation and Recovery Act regulations on the disposal of hazardous and special wastes should greatly reduce environmental risks from these wastes. This is particularly important in the South Central Region (Federal Region VI), where noncombustible solid wastes and industrial sludges from electric utilities are expected to increase sharply between 1975 and 2000.

Impacts of Synthetic Fuels

Disposal of the enormous volume of solid waste associated with surface oil shale retorting represents one of the largest environmental uncertainties associated with future production of synfuels. The richest oil shale deposits in the nation are concentrated in a small area of northwestern Colorado, northeastern Utah, and southwestern Wyoming. Under the High Growth Scenario, 1.5 billion tons of oil shale waste would be generated annually in this area by the year 2000.

Coal liquefaction and coal gasification are also projected to generate substantial volumes of solid wastes in the Mountain Region (Federal Region VIII) by 2000. Further, the introduction of more coal-fired utilities to this Region would increase ash and sludge disposal requirements there. While coal liquefaction and gasification plants and coal-fired utilities are not apt to be concentrated in as small a geographic area as the oil shale industry, the wastes that they generate may create localized environmental problems in coal regions.

Oil shale retorts, coal liquefaction and gasification plants, and coal-fired utilities place two additional environmental burdens on Federal Region VIII. The first is air emissions, particularly SO_x; in 1975, the Mountain Region had relatively low SO_x levels. The second environmental burden is water consumption. The Mountain Region has limited water availability--both physically and legally. The water requirements for these processes may pose water-use conflicts as well as the threat of degradation of water quality.

Although Federal Region VIII encompasses a vast expanse of land, the location of prime oil shale and coal deposits tends to concentrate energy development in relatively few areas. This concentration will heighten local environmental impacts and threaten relatively pristine areas.

14.3.3 Alternative Energy Scenarios

For purposes of this analysis, the environmental trends associated with the following energy scenarios are evaluated:

- High Conservation
- High Solar
- High Synfuels
- Low Nuclear

High Conservation Scenario

In the past, the availability of cheap energy in all forms has encouraged energy consumption. However, with the arrival of energy shortages and high prices, the incentive for energy conservation has increased dramatically. A recent Council on Environmental Quality (CEQ) report noted:

> Throughout our economy, substantial reductions in future energy requirements can be made without adopting measures which involve important changes in lifestyles. These possibilities have been examined in considerable detail by others. The results indicate that today's fuel consumption levels can be reduced by more than 40 percent through technical improvements which reduce the energy per unit of output. Only modifications that are economic today on a life-cycle cost basis are incorporated in this estimate.[26]

Based on this observation, CEQ has postulated a high-conservation energy future known as the "Good News" Scenario. This scenario is compared with the High Growth Scenario for the year 2000 in Table 14-3. In the first three areas of energy supply, the CEQ scenario calls for:

- A substantial decrease in oil and gas use between 1977 and 2000, compared to a moderate increase under High Growth conditions.
- A dramatic increase in solar use, compared to only a small one in the SEAS scenario.
- A significant increase in nuclear energy, but not nearly as great as that of the High Growth Scenario.

TABLE 14-3
COMPARISON OF CEQ GOOD NEWS SCENARIO AND SEAS HIGH GROWTH SCENARIO
(QUADS OF PRIMARY FUEL)

Energy Supply	1977	2000	
		CEQ Good News	SEAS High Growth
Oil and Gas	56.5	40	60.2
Solar[a]	4.2	19	7.0
Nuclear	2.7	8	13.2
Coal	14.1	18	44.0
TOTAL	77.5	85	124.4

[a] The solar category includes all renewable energy sources. The 1977 total includes 1.8 quads from biomass, which is usually not included in national energy statistics.

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[26] Council on Enviornmental Quality, The Good News About Energy, U.S. Government Printing Office, Washington, D.C., 1979, p.9.

But the largest difference between the CEQ scenario and the High Growth case is in projected levels of coal use. The Good News Scenario calls for only a 28 percent increase in coal supply between 1975 and 2000, whereas in the High Growth Scenario coal production is expected to increase by over 210 percent. The lower level would lead to much lower environmental impacts from the coal fuel cycle under the Good News Scenario by the end of the century.

Solar energy is the only source from which the Good News Scenario calls for more energy than the High Growth case by 2000. Solar technologies themselves produce virtually no pollutants, and therefore little direct environmental impact would be expected from such an increase. However, the indirect effects of solar development, such as potentially increasing levels of toxic chemicals discharges by solar component manufacturers, may be significant.[27]

The Good News Scenario would hold emissions of sulfur and nitrogen oxides close to their 1975 levels. By assuming a reduced rate of demand for energy, the energy future postulated by CEQ would lead to the accelerated retirement of older, less efficient plants which generally have higher rates of emission. However, emission levels would still be expected to remain near 1975 levels in the Great Lakes Region (Federal Region V) and other areas where large numbers of old coal-fired plants are located.

However, the Good News Scenario would greatly offset expected increases in SO_x and NO_x emissions in those regions which, under the High Growth Scenario, are projected to have new coal-fired electric and industrial capacity. In particular, under the Good News Scenario, the South Central Region (Federal Region VI) and the Mountain Region (Federal Region VIII) would not experience the substantial growth in SO_x and NO_x emission levels projected under High Growth conditions. Similarly, the large increases in noncombustible solid waste and industrial sludge generation associated with the operation of new coal-fired facilities projected for these regions would be offset by the conservation effort postulated by CEQ.

Under CEQ projections, the demand for synfuels could virtually be negated by conservation, depending upon the oil import level assumed. Clearly, the coal production projection of the Good News

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[27] As mentioned previously, an in-depth analysis of the indirect effects of solar energy is beyond the scope of this chapter. The Technology Assessment Division of the Office of Technology Impacts in DOE is currently sponsoring such an analysis. Results of this analysis are expected to be available in late 1980.

Scenario suggests little coal liquefaction and gasification activity. Oil shale development, in all probability, would be greatly slowed by lower demand for oil products. Both these possibilities would greatly alleviate the environmental impacts to Federal Region VIII posed by the synfuels forecast under the High Growth Scenario. With the Good News Scenario, energy-related environmental impacts to that region would be minimal compared to those postulated for High Growth.

A strong conservation effort would have long-term beneficial environmental impacts throughout the nation. Conservation is the most direct way to reduce energy-related pollutant levels. While the feasibility of meeting Good News Scenario energy projections is subject to debate, its potential environmental benefits seem clear.

High Solar Scenario

Solar technologies can be used to produce a wide variety of fuel and energy types. Photovoltaic, solar thermal, hydroelectric, and wind technologies can be used to convert biomass into electricity or process heat, high-Btu gas, or liquid fuels such as gasohol. Solar heating and cooling units can be used to supplement residential and commercial use of oil, gas, and electricity; and agricultural and industrial process heat techniques can be used in place of oil, natural gas, and coal in farming and industrial settings.

Thus a scenario postulating high solar use can reduce the demand for energy from oil, gas, coal, and nuclear sources. And because most solar-based systems in operation release only negligible amounts of pollutants, a high penetration of solar technologies into the energy market could have a significant impact on environmental pollutant trends.

The indirect pollutants--that is, those associated with manufacture and construction of solar plants and equipment--are likely to be substantial. But these releases would come from the non-energy industries (such as steel, cement, and plastics) stimulated by the demand for solar hardware. Since our present capability extends only to those pollutants related to the operation and maintenance of the energy facilities themselves, indirect pollutants are not discussed here.

In examining the potential environmental impacts of increased solar use, it is important to assess for which fuels solar technologies can be substituted. In the discussion that follows, the environmental impact of solar use will be addressed by energy demand sector.

Residential Solar Use. Solar heating and cooling of buildings (SHACOB) systems offer a replacement for, or supplement to, home and commercial use of oil, gas, or electricity. If electric heating and cooling of residences and businesses--fueled by conventional electric utilities--can be supplemented or replaced by SHACOB systems, the reduction in electricity demand will also reduce power plant emission levels.

In 1975, residential and commercial fuel use accounted for 5 percent of national sulfur oxide emissions. While these emissions represent a relatively small portion of the national total and are not expected to become a significant portion of national SO_x emissions by 2000, they may add to local ambient problems in urban areas. Increased use of SHACOB technologies could lead to reductions in these emissions.

Wood stoves may become a growing source of residential heat as the cost of home heating rises. Wood use may play a significant role in future residential fuel use patterns of the New England Region (Federal Region I) where trees are abundant and winters are severe. Because relatively little in the way of emission controls would be expected for home use of wood stoves, particulate emissions from residential wood use could be substantial in Federal Region I by 2000. Wood stoves are an example of a solar technology (biomass) that may lead to higher pollutant levels than conventional fuel use.

Solar Electric Use. Numerous technologies--including photovoltaic, solar thermal, wind, and biomass--can be used to produce electricity. These technologies can be deployed at central power stations or, in some cases, sited for residential or community use. Such deployment, however, is not expected until after 1990. The operation of photovoltaic, solar thermal, and wind electric sources produces virtually no pollutants. Thus if these solar electric sources are assumed to be substituted for new coal-fired utilities in the High Growth Scenario, a corresponding reduction can be expected in particulates, SO_x, NO_x, noncombustible solid wastes, and industrial sludges from new coal-fired facilities by 2000.

Solar electric technologies do not have the siting flexibility that conventionally fueled utilities do. For photovoltaics, the amount of solar radiation in a given area strongly affects the size requirement of collectors and the overall economics of the system; for example, a photovoltaic collector array suitable in California would be inadequate in Maine. Thus initial market penetration of many solar technologies is likely to be in the Sunbelt. Since in the High Growth Scenario the South Central Region (Federal Region VI) is projected to experience sharp increases in coal-fired electricity and its associated pollutants, a high concentration of photovoltaic or solar thermal technologies in Federal Region VI could help reduce forecast increases in coal-related pollutant levels there.

Biomass utilities, because they would burn fuel (wood, crop residues, etc.) much as a conventional utility, would have higher pollutant levels than would photovoltaic, solar thermal, or wind systems. Biomass utilities would release more particulates per unit of energy than would new coal-fired plants, but far less SO_x and NO_x. Thus the air quality of Federal Regions IV and X would probably not be adversely affected if biomass utilities were substituted for some of the projected coal-fired capacity.

Noncombustible solid waste and sludge levels from biomass would also be lower. If silvicultural plantations (growing trees for energy use) accompany these utilities, however, large amounts of agricultural runoff may be part of the pollutant releases of the biomass fuel cycle. Silvicultural plantations are best suited to the moist climates of the Southeast and Northwest Regions (Federal Regions IV and X).

Agricultural and Industrial Use. Agricultural and industrial process heat (AIPH) technologies can meet some of the demand for conventional fuel use, but it is unlikely that such technologies can displace significant amounts of future coal use by industry. Again, Sunbelt states are a primary location for AIPH technologies, and industrial use of coal is expected to increase dramatically in the South Central Region (Federal Region VI). However, AIPH techniques will probably be best suited to relatively small industrial applications through 2000, and some reduction in pollutants can be expected due to their use.

Agricultural and industrial energy use can also be supplemented by small biomass conversion plants that could convert agricultural and forestry wastes into gaseous and liquid fuels. Gasohol use has already begun in the farm belt and may increase substantially in the Central Region (Federal Region VII) by 2000. Pollutants from the conversion processes themselves are not expected in large amounts, although solid waste volumes may become substantial over time. Combustion of biomass-based fuels should be cleaner than that of fossil fuels.

Summary of Scenario Differences. A high penetration of solar technologies into the national energy mix would reduce national levels of energy-related pollutants projected under High Growth conditions. Non-biomass technologies are generally free of pollutants from direct operation and maintenance, and deployment of these technologies should reduce the energy-related pollutant levels projected according to the High Growth Scenario. This would be important in regions expected to have high growth in SO_x or NO_x levels. The fuel cycles of the various biomass technologies do have pollutants associated with them, and in some cases (e.g., solids runoff from silvicultural plantations) they may be substantial. However, if biomass fuels were substituted for coal, their increased use under the High Solar Scenario would reduce overall pollutant levels assumed in the High Growth Scenario.

High Synfuels Scenario

On July 15, 1979, the President announced a new energy program; its primary objective was to reduce oil imports by 50 percent by 1990. To this end, one of the major initiatives proposed was development of a synthetic fuels industry over the next 10 years. The President's goal is the production of 1.5 million barrels per day (3 quads) of oil from coal liquefaction and 0.4 million barrels per day (0.8 quads) of oil from oil shale by 1990.[28]

To assess the environmental consequences of this initiative, the following assumptions are made for this analysis:

- The increased oil obtained from synfuels will replace oil obtained by imports.
- Synfuels development will be concentrated in three regions of the country, the Mountain Region (Federal Region VIII), the Great Lakes Region (Federal Region V) and the Middle Atlantic Region (Federal Region III).
- By 1990, the President's goals will be achieved. By 2000, coal liquefaction will triple from 1990 levels and oil shale production will be increased to 5 quads, the level projected in the High Growth Scenario.

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[28] In March, 1980, Congress agreed to a $20 billion program to develop synthetic fuels. A seven-member government corporation was established to allocate funds over the next 12 years. The corporation must report to Congress in 1984, after which it becomes eleigible to receive $68 billion in additional funds. The corporation will provide loan and price guarantees as incentives to private industry to produce synthetic fuels. Under this program, production of synthetic fuels is expected to range from 1.5 to 2.5 million barrels/day (oil equivalent) by the mid-1990's.

The assumption that liquefied coal and shale oil will replace imported oil does not imply that the development of a synfuel industry will displace domestic oil exploration and production. Thus the environmental pollutants associated with continental, offshore, and Alaskan oil production will not be offset by synthetic fuel production.

Synthetic liquids are expected to be clean-burning fuels in comparison to the direct use of coal. However, their emission characteristics are not expected to be significantly different from those of conventional oil. Thus use of synfuels in place of imported oil will not result in large changes in projected oil-use-related emissions; however, the production of these fuels would cause increased environmental impacts.

As replacements for imported oil, synfuels would be used primarily in residential and commercial, industrial, and transportation applications. At present, it does not appear likely that electric utilities would use synthetic liquid fuels. Therefore, while they might displace some coal from industrial applications, synfuels would not have a large impact on the electric utilities' use of coal and its associated pollutant releases.

The production of synfuels in the West has been supported by several documents. A recent analysis was presented by the U.S. Department of Energy's Assistant Secretary for Environment to an interagency task force studying the accelerated deployment of commercial-size synthetic liquid fuel plants.[29] This document focused upon constraints to siting synfuel plants. Based upon coal reserves, water availability, and air pollution constraints, this study concluded that the most likely sites for liquefaction plants would be in Montana, Wyoming, Colorado, North Dakota (all in the Mountain Region [Federal Region VIII]); West Virginia (in the Middle Atlantic Region [Federal Region III]); and Illinois (in the Great Lakes Region [Federal Region V]). Oil shale activity, concentrated where the most economic oil shale reserves are located, would be in Colorado, Utah, and Wyoming (also all in the Mountain Region [Federal Region VIII]).

As previously discussed, a major oil shale development and coal liquefaction program would result in significant environmental impact to the Mountain Region. The problems in attempting to quantify most environmental impacts make it difficult to assess whether the potential environmental consequences of synthetic fuel development are too severe to support a program of this magnitude.

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[29] U.S. Department of Energy, Assistant Secretary for Environment, Office of Technology Impacts, Environmental Analysis of Synthetic Liquid Fuels, July 12, 1979.

The Prevention of Significant Deterioration (PSD) requirements of the Clean Air Act Amendments may conflict with the High Synfuels Scenario in this region. According to the Department of Energy, this conflict is not likely to occur with the levels projected for 1990.[30] However, a tripling of synfuels activity by 2000 could use up the allowable PSD increments in many areas of Federal Region VIII. The DOE environmental analysis cited 41 counties in the United States that would not be constrained by PSD, water, or coal reserves. A recent Oil Shale Environmental Impact Statement[31] indicated that production levels of 2 million barrels per day could result in violations of Class II regulations (the Clean Air Act as amended in 1977).

Air quality would not be the only important environmental impact of a high synfuels scenario. Others involve water availability, containment of toxic substances, increased coal mining, and contamination of surface and ground water. In the long term, the increased release of CO_2 may be a factor.

The major uncertainty with oil shale is whether spent shale waste can be disposed of without causing unacceptable environmental damage. This problem, as it relates to water, is discussed in detail in Chapter 6. The problem is that huge volumes of spent shale are forecast under both the High Growth and High Synfuels Scenarios. These wastes contain toxic substances, and if wastes are disposed of improperly, these substances can contaminate surface and ground water. Development of in situ oil shale technology would alleviate much of the solid waste problem. However, in situ oil shale retorting could contaminate ground water.

The environmental problems associated with coal liquefaction are different from those associated with oil shale. Coal liquefaction problems primarily involve waste disposal, worker safety, and safe transportation and handling. The wastes associated with coal liquids contain tars, some of which contain toxic and carcinogenic materials. Isolating these toxic wastes and preventing the materials from entering the ground water are important environmental requirements. The liquid itself may also contain toxic and carcinogenic materials that may be released when the liquid is combusted.

Water availability probably would not be a constraint on the projected 1990 levels of coal liquefaction and oil shale. This conclusion was reached in several recent water assessment studies. An assessment of synthetic fuels by the Energy Research and Development Administration in 1976 indicated that the upper Missouri River could support up to 6 million barrels per day of synthetic fuels.[32] A recent Colorado water assessment indicated that the region could supply enough water for a 1.3 million barrel per day industry.[33]

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[30] U.S. Department of Energy, Assistant Secretary for Environment, Office of Technology Impacts, Environmental Analysis of Synthetic Liquid Fuels, July 12, 1979.

[31] U.S. Department of Energy, Programmatic Oil Shale Environmental Impact Statement, Draft, March 1979.

The overall assessment is that by 1990, Federal Region VIII could probably absorb the amount of oil shale processing and coal liquefaction planned in these scenarios. However, the levels predicted for 2000 may produce conflicts for water resources and air quality. These conflicts are more probable for surface oil shale retorting than for coal liquefaction.

Thus, while a synthetic fuels industry would offer the United States a measure of energy independence, its environmental impacts are likely to be significant. The SEAS High Growth Scenario assumes that enough emphasis will be placed upon synthetic fuel development (especially oil shale) to pose potentially serious environmental problems in the Mountain Region by 2000. The emphasis in this scenario is on oil shale rather than coal synthetic fuels. A High Synfuels Scenario such as the one discussed here forecasts still larger potential environmental impacts, accompanied by substantial reduction of foreign oil imports.

Low Nuclear Scenario

Following the Three Mile Island accident, it was thought possible that no new nuclear plants would come on line after 1990. DOE's Assistant Secretary for Policy and Evaluation (P&E) proposed such a scenario and presented the results in a recent Second National Energy Plan published by the Department of Energy.[34] Since the P&E base case scenario is similar to the SEAS High Growth Scenario, the changes in pollutant levels forecast by P&E as a result of a low nuclear power assumption can be compared to High Growth Scenario as well.

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[32] Energy Research and Development Administration, Synthetic Liquid Fuels Development: Assessment of Critical Factors, Volume III, ERDA 76-129/3, May 1977.

[33] Water Resources Council, Water Resource Assessment for Upper Colorado River Basin, Section 13(a), Draft, undated. Also, see Chapter 4 of White, I.L. et al., Energy from the West: Policy Analysis Report, U.S. Environmental Protection Agency, Office of Energy Minerals and Industry, Washington, D.C., 1979. This study concludes that high levels of energy development could contribute to an overall water shortage in the Upper Colorado River Basin by 2000.

[34] U.S. Department of Energy, National Energy Plan II, Appendix: Environmental Trends and Impacts, May 1979.

The P&E Low Nuclear Scenario assumes a 7-quad decrease in nuclear energy by 2000 as a result of a postulated nuclear moratorium. This decrease in energy supply is assumed to be offset by a reduction in demand (3 quads), and increases in coal use (2 quads), oil imports (1 quad), and biomass, geothermal, and hydroelectric power (1 quad).

The Department of Energy evaluated the environmental impacts of such a moratorium in comparison to the P&E base case scenario as part of its analysis of the Second National Energy Plan.[35] The assumed nuclear moratorium is projected to result in the following differences in pollutant levels nationally (in comparison to the base case):

- Sulfur oxides and nitrogen oxides increase 2.47 percent
- Particulates increase 0.6 percent
- Sludge increases 5.0 percent
- Noncombustible solid waste increases 3.3 percent
- Radioactive waste burial is reduced 43 percent

The environmental benefits associated with a nuclear moratorium scenario would be a reduction in the steady-state release of radioactive material and a reduction in radioactive wastes requiring burial. In addition, the risks of a nuclear accident would be reduced. Environmental costs of a nuclear moratorium would primarily be small increases in sulfur oxide and nitrogen oxide emissions and sludge generation. A nuclear moratorium could result in some regional shortages in electric capacity, which could in turn cause delay in retiring older fossil fuel utilities. As these older plants are generally more polluting than new coal-fired utilities, the increases in SO_x and NO_x emissions may be larger than those projected above. However, in such an event, projected sludge generation levels would decline because these plants are not equipped with flue gas scrubbers.

Projected increases in nuclear energy between 1990 and 2000 in the High Growth Scenario are concentrated in the Southeast and Great Lakes Regions (Federal Regions IV and V). Numerous nonattainment areas for SO_2 are located in the northern parts of Federal Region IV and in the states of Ohio and Illinois in Federal Region V. Reductions in SO_x levels projected in these regions between 1975 and 2000 result in part from the use of nuclear power plants rather than coal to generate electricity.

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[35] U.S. Department of Energy, National Energy Plan II, Appendix: Environmental Trends and Impacts, May 1979.

However, these reductions are not expected to be sufficient to alleviate the sulfate transport and visibility problems caused by the emissions. Replacing projected nuclear reactors with coal-fired utilities in these regions would result in a 5 percent increase in sulfur oxide emission levels there by 2000. Thus a nuclear moratorium would result in increased air pollutant emission levels in those areas where coal is used to make up reductions in electric capacity, either through the prolonged operation of older plants or the construction of new coal-fired utilities.

14.4 SUMMARY AND CONCLUSIONS

This limited examination of energy-related pollution trends projected under SEAS High Growth conditions identifies four major environmental problems for the year 2000:

- Continued high levels of sulfur oxide emissions
- Substantial growth in nitrogen oxide emission levels
- Enormous increases in solid waste generation
- Impacts associated with synthetic fuel production

Projected increases in coal use by utilities and industry are largely responsible for the first two problems identified and make a substantial contribution to the third. The production and use of synthetic fuel from coal and oil shale are projected to be major sources of solid wastes by 2000; in addition, the likely concentration of the industries in the Mountain Region (Federal Region VIII) would place a heavy environmental burden on this relatively pristine area.

14.4.1 Pollutant Effects of Energy-Related Changes

As utilities and industry increase their use of coal, regions whose primary energy sources have been oil and gas are expected to experience sharp increases in sulfur oxide and nitrogen oxide emissions and noncombustible solid waste and sludge generation--for example, the South Central Region (Federal Region VI). In those areas where coal use (and consequently SO_x and NO_x levels) are currently high, some reduction in emission levels are expected as older, more polluting plants are retired and newer, more stringently controlled plants are bought on-line--for example, the Great Lakes Region (Federal Region V). However, these older plants are expected to remain a significant source of pollution through 2000. The environmental controls (electrostatic precipitators and flue gas scrubbers) associated with newer plants are projected to substantially reduce plant air emissions, but to lead to large increases in solid waste volumes.

The solid waste volumes associated with the surface retorting of oil shale are likely to pose severe environmental problems in the relatively small areas in which oil shale development is expected to take place. In addition, the development of liquefaction and gasification technologies in the Mountain Region (Federal Region VIII) will place further demands on the region's air quality, water availability, and solid waste disposal capabilities.

The energy-related environmental trends of the SEAS High Growth Scenario underscore the centrality of coal production and use to both future energy supply and energy-related environmental impacts. Different assumptions for future energy mixes will result in different projected environmental pollutant patterns, depending on the extent to which coal is used. In scenarios in which new coal-fired plants are replaced by other forms of energy (e.g., solar), reduced levels of SO_x, NO_x, and industrial sludge can be expected, particularly in those regions where oil and gas have been the predominant fuels.

14.4.2 Timeframe for Environmental Impacts

Because one important facet of U.S. energy policy is to promote the domestic production of energy and reduce the importation of oil, production and use of coal are likely to increase substantially beginning in the 1980s. Compliance with existing environmental regulations should minimize, but will not eliminate, the environmental impacts associated with this energy transition.

Alternative energy strategies will have differing impacts on energy and environmental goals. Conservation measures and the use of solar technologies appear to be the most environmentally benign energy strategies of those examined here. However, many solar technologies will not make a significant contribution to energy supply by 2000 without a strong national program to promote solar energy use and resolve the technical, institutional, and economic barriers to solar development. Expanded residential use of solar devices can be expected within the decade, but advanced solar technologies will not be widely used until after 1990.

The President's recent emphasis on synthetic fuel development to reduce imported oil levels is expected to lead to intensive development of oil shale and coal liquefaction and gasification technologies for operation in the late 1980s and early 1990s, along with development of solar technologies.

A nuclear moratorium would encourage importation of foreign oil, use of coal, and a decrease in the rate of energy demand. While the conservation projected along with a nuclear moratorium would have environmental benefits, the increased use of coal would exacerbate coal-related environmental problems. However, the problems of radioactive waste disposal and the possiblity of nuclear accidents would be greatly reduced by a moratorium on reactor construction and operation.

14.4.3 Energy and Environmental Goals

The degree to which energy policy and environmental protection goals conflict with one another has been an area of increasing debate in recent years. This chapter has emphasized that energy production and use are likely to be an increasing source of environmental pollution through the end of the century. It is clear that in achieving energy independence, we must pay an environmental price. The development of programs that can mediate national energy and environmental goals is one of the challenges of the 1980s.

APPENDIX A
DESCRIPTION OF SEAS

A.1.1 HOW SEAS WORKS

The logic of the SEAS model is relatively simple: the economic and energy modules simulate national activity levels for over 500 SEAS sectors; the regionalization module disaggregates these data to one of several possible geographic subdivisions; and the environmental modules use data on emission coefficients, control strategies, and economic and energy activity levels to calculate regional emissions and resource requirements.

SEAS logic is illustrated in Figure A-1. Rectangles denote SEAS modules, arrows track information flows, and ovals indicate assumptions which must be entered into the model. Table A-1 presents the kinds of input assumptions which are the basis for SEAS simulations. The following sections describe the various modules in some detail.

A.1.2 ECONOMIC MODULES

SEAS uses three economic modules: INFORUM, INSIDE, and ABATE. Adapted from a model developed by the University of Maryland, INFORUM is a 185 sector input-output formulation of the U.S. economy that employs a set of dynamic, time-dependent interindustry coefficients and exogenously specified values for labor force participation, target unemployment rates, and average levels of per capita disposable income as the basis for its projections of the value of goods produced in specific sectors of the economy. Table A-2 indicates the type of information which can be projected by INFORUM. The 185 INFORUM economic sectors are consistent with the standard industrial classification (SIC) code developed by the Department of Commerce.

The INSIDE module further disaggregates the 185 INFORUM economic sectors into roughly 350 process and product sectors. For example, INFORUM has one sector for chemicals and INSIDE contains data on 40 different chemicals. This disaggregation is performed only when a process is significant in terms of pollution generation or energy consumption. The ABATE module calculates the capital and operating and maintenance (O&M) costs associated with pollution abatement strategies.

An important feature of the economic modules is their interaction. After a preliminary economic projection has been made, the main economic modules, INFORUM/INSIDE, are calibrated to the energy strategy, the energy investments, and the pollution investments generated by the ESNS (see next section), ENERGY INVESTMENT, and ABATE modules. Thus, if parameters in these modules are altered, so are the economic projections and the industry outputs from non-energy

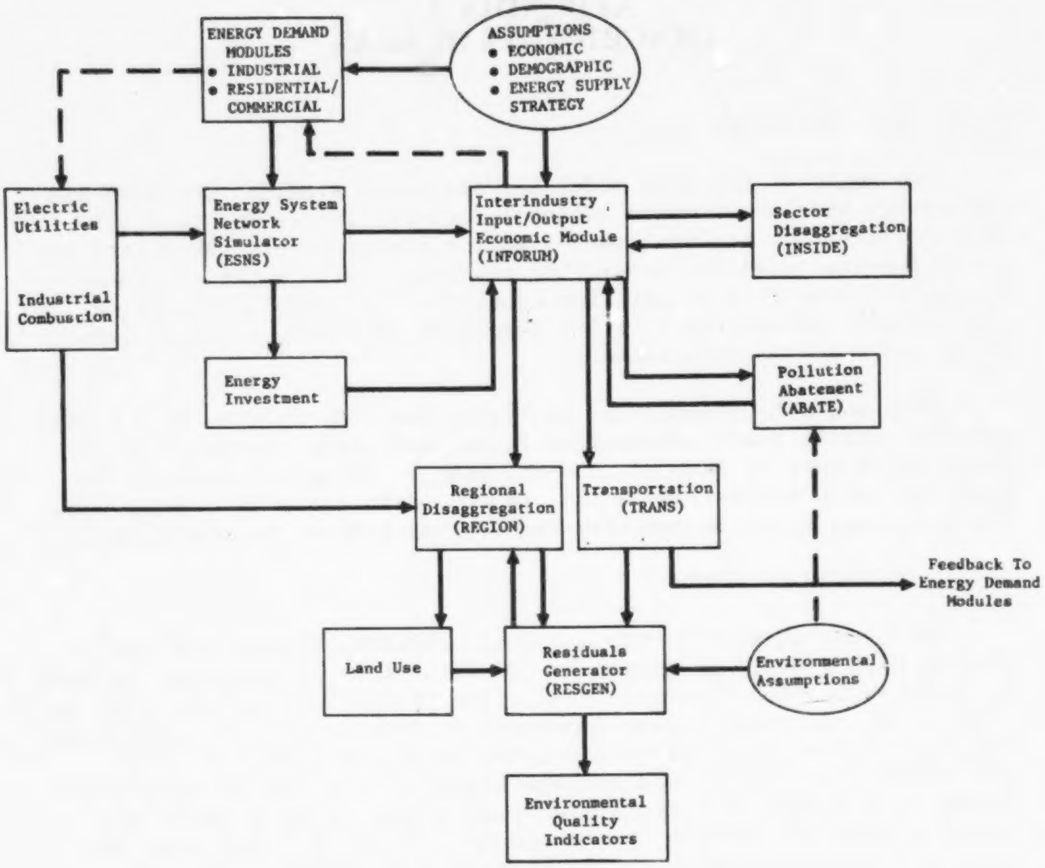
ENERGY DEMAND MODULES
• INDUSTRIAL
• RESIDENTIAL/ COMMERCIAL
ASSUMPTIONS
• ECONOMIC
• DEMOGRAPHIC
• ENERGY SUPPLY STRATEGY
Electric Utilities
Industrial Combustion
Energy System Network Simulator (ESNS)
Interindustry Input/Output Economic Module (INFORUM)
Sector Disaggregation (INSIDE)
Energy Investment
Pollution Abatement (ABATE)
Regional Disaggregation (REGION)
Transportation (TRANS)
Feedback To Energy Demand Modules
Land Use
Residuals Generator (RESGEN)
Environmental Assumptions
Environmental Quality Indicators

FIGURE A-1
SEAS FLOW DIAGRAM

TABLE A-1
TYPICAL SEAS INPUT ASSUMPTIONS
(Comprehensive mode)

Energy	o Market penetration of energy technologies
	o Regional location of energy technologies
	o Efficiencies of energy supply technologies
	o Depreciation of existing energy supply technologies
	o Fuel switching capabilities
	o Transportation regulations
Economics	o GNP
	o Population
	o Unemployment
	o Work force
	o Composition of investment
	o Technology assumptions
	o Energy investment costs
Environment	o Emissions regulations
	o Degree of compliance
	o New legislation
	o Removal efficiencies
	o Process change

TABLE A-2
ECONOMIC INFORMATION PROVIDED BY INFORUM

- Labor Force[a]
- Gross National Product[a]
- Disposable Income
- Final Demands
  - Personal consumption
  - Government purchases
  - Capital investment
  - Construction
  - Inventory changes
  - Net imports
- Sector Productivity[a]
- Labor Requirements by Sector
- Sector Outputs (million of dollars)

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[a] Depending upon how the model is used, some of these variables will be specified by the user.

sectors of the economy. The final output of the SEAS energy and economic modules is a forecast to the year 2000 of production levels in over 500 sectors of the economy. Examples of SEAS energy and non-energy sectors appear in Figure A-2.

A.1.3 ENERGY MODULES

Analysis of energy strategies takes place after an initial economic projection has been made. Three demand modules (of industrial, transportation, and residential/commercial energy users) use these output estimates in conjunction with fuel-specific energy coefficients to calculate fuel demand in physical units (Btu) for a given year. These modules contain parameters that reflect user assumptions about the level of conservation measure implementation, the impacts of fuel prices on demand, and the prevailing policy toward fuel substitution. The demand projections are translated into requirements for resource extraction through the Energy System Network Simulator (ESNS), an accounting framework that presents the technological alternatives that exist at each processing step in the supply structure. Once a supply strategy has been selected by the user, the energy investment model estimates the amount and mix of capital goods required to construct the necessary additions to energy production capacity. This forecast is then fed back into INFORUM and modifies the initial economic projections.

A.1.4 REGIONALIZATION MODULES

The REGION module distributes energy and economic activities to a number of geographic subdivisions. The most commonly used regions include:

- Federal Regions
- States
- Air Quality Control Regions (AQCRs)
- Standard Metropolitan Statistical Areas (SMSAs)
- Aggregated Sub-Areas (ASAs)

Each subdivision is an aggregate of individual counties. The ELECTRIC UTILITIES module, the INDUSTRIAL COMBUSTION module, and the COAL MINING module were developed to improve the regional distribution of energy activities. Even though they are classified as energy modules, their primary function is regionalization.

AN EXAMPLE OF A SEAS ENERGY SECTOR

- Non-Electric Industrial Energy Use
  - Coal-Burning Plants
    - Existing Plants
    - Future Plants
      - Future Plants Under SIP Standards
      - Future Plants Under BACT Standards
      - Future Plants Under NSPS Standards
  - Oil-Burning Plants, Etc.

EXAMPLE OF A SEAS NON-ENERGY SECTOR

- Aluminum Production
  - Bauxite Refining
  - Aluminum
    - Primary
      - Hall-Heroult Process
        - Pre-Baked Anode
        - Horizontal Soderberg
        - Vertical Soderberg
      - Alcoa Process
    - Secondary

FIGURE A-2
EXAMPLES OF SEAS SECTORS

A.1.5 ENVIRONMENTAL MODULES

SEAS uses four environmental modules: the RESGEN module, which calculates point source emissions; the TRANS (transportation) and LAND USE modules, which calculate non-point source discharges; and the ENVIRONMENTAL QUALITY INDICATOR module, which translates sulfur oxide and particulate emissions data into several environmental quality indicators.

RESGEN is the primary environmental module of SEAS. It calculates the environmental pollution and the resource consumption associated with various levels of energy/economic activity and pollution abatement. The module estimates how much pollution would be generated by production processes operating without environmental controls (gross pollution). As a result of environmental regulations, pollution controls are added to industrial processes and "net" pollution is calculated. Net pollution is thus a function of the activity level, the gross pollution produced and the pollution control strategy. Furthermore, the emissions "captured" by pollution control devices must be disposed of; so SEAS keeps track of these "secondary residuals," and can estimate how much solid waste would result from a reduction in particulate emissions. A schematic of the basic RESGEN methodology is presented in Figure A-3.

The three factors which determine the extent of environmental pollution and the demand for natural resource are: economic/energy activity levels, gross emissions factors, and the degree of pollution control. Thus, emission rates for net and secondary pollutants are sensitive to these policy strategies.

The LAND USE and TRANS modules account for non-point source pollution. They also are sensitive to environmental regulations. The TRANS module can be used to evaluate the impacts of alternative regulations and changes in the mix of transportation modes on emissions from this sector.

The final environmental module is the ENVIRONMENTAL QUALITY INDICATOR module, which presents particulates and sulfur oxide emissions data in terms of:

- o Emissions per square mile
- o Average annual ambient concentrations
- o Emissions per cubic meter of ventilation flow
- o High population densities and concentrations

- **Basic Methodology:**
  - **for each pollutant for each sector the following steps are performed:**

Economic Output for Sector (from INFORUM) X **Pollution Coefficient*** $\dfrac{\text{Amount of Pollutant (tons)}}{\text{Unit of Output} \begin{pmatrix} \$10^6 \\ 10^{12}\ \text{Btu} \\ 10^6\ \text{Tons} \end{pmatrix}}$ = **Gross Residual**

Gross Residual X **Removal Efficiency*** X **Fraction of Waste* Load Treated** = **Captured Residual**

Gross Residual — **Captured Residual** = **Net Residual Released**

*Data in RESGEN data base for each pollutant identified for each sector.

FIGURE A-3
RESGEN

A.2.1 THE SEAS DATA BASE

SEAS modules use an extensive data base containing detailed environmental, energy, and economic information. Every effort is made to maintain current data through frequent updating and validation. The many types of information are presented in a consistent manner with much of the information keyed to specific industrial activities. As a result, the SEAS data base is now considered a resource in its own right.

The more than 50 data files that comprise the SEAS data base contain information from numerous government reports and documents by and communication with university personnel, government laboratories and contractors, and various industry trade associations. Government reports include, for example, FPC data on powerplant locations and capacities, DOE studies of energy technology costs and emissions and effluents, EPA effluent limitations guidelines development documents, and Bureau of the Census and other Department of Commerce publications and data bases. The following sections describe the types of information in some of these data files.

A.2.2 ENVIRONMENTAL DATA

The environmental data base contains information on the release and control of a comprehensive range of environmental pollutants associated with industrial activity throughout the economy. Detailed information is provided on each pollutant released to air, water, or land by each manufacturing and industrial sector. These data relate pollution production to industrial activity and are called pollution coefficients. In addition, information concerning abatement standards is provided for each pollutant on an industry or process-specific basis, as appropriate. These data describe not only criteria air and water pollutants, but various toxic substances and trace elements released to air and water. Data are also included concerning numerous types of solid waste, including radioactive wastes, which are released to air or water.

In addition, other environmental information is provided for various industries and processes including land use, water use (including water consumption), and several indices of occupational hazard (e.g., deaths, injuries) associated with various activities. Further, the data base contains information on the production of secondary residuals, such as scrubber sludge, that are produced by environmental control processes.

An important characteristic of the environmental data base is that the data have been disaggregated to that level of detail necessary to reflect significant differences in the polluting characteristics of alternative manufacturing processes. For example, different data are provided for electric arc and open hearth steel production. In the nuclear fuel cycle, separate environmental data are provided for surface and underground uranium mining, milling, and enrichment.

The environmental data base is also designed to store information on regional variations in the pollution characteristics of various industries. Thus, surface coal mining in Pennsylvania is characterized by different pollutant releases than coal mining in Wyoming. In addition, different regulatory standards imposed in different states are included in the data base.

A.2.3 CAPITAL AND OPERATING COST DATA

This data base provides detailed information on the capital and operating expenditures associated with industrial efforts to control pollution. It also contains information on the unit capital expenditures required to construct various energy facilities. As with the environmental data base, energy cost data are provided in great detail for each phase of an energy fuel cycle and for alternative processes in each phase of a fuel cycle.

A.2.4 REGIONALIZATION OF INDUSTRIAL AND ENERGY ACTIVITY

An important part of the SEAS data base provides detailed information on the current and anticipated locations of all industrial and energy-related activities. This information is provided at the county level, in the form of county shares (fractions) of total activity. For selected energy industries, however, auxiliary files specify a sequence of individual facilities that will come on line as energy demand grows.

A.2.5 ADDITIONAL TECHNOLOGICAL AND ECONOMIC FACTORS

This appendix has described major components of the comprehensive SEAS data base. Examples of miscellaneous additional data included in the SEAS data base are: OBERS forecasts of future demographic trends, soil loss data for agricultural land use, compliance data and schedules for pollution standards, and industrial energy consumption and conservation potential factors.

One example of data which are actually part of the system is information on current and projected interindustry transactions reflecting material substitutions over time. In addition, data are provided on anticipated technological change from one process to another within a particular sector, and on changes in consumption and transportation patterns. Data are also provided on process losses in various stages of energy fuel cycles. Most of these data sets can be modified by the user, but specific values are stored in the data base for use in the event that no changes are made.

APPENDIX B
ADDED DETAIL ON SEAS SCENARIO ASSUMPTIONS

This appendix expands the description of SEAS scenarios presented in Chapter 2. The order of the discussion is the same: economics and population, energy supply and demand, and environmental regulations.

B.1.1 GROWTH IN THE ECONOMY AND POPULATION

The growth in Gross National Product (GNP) assumed in both scenarios is shown in Table B-1. The difference between GNP in the two scenarios in 2000, based on the assumed average growth rates of 3.5 percent and 2.6 percent per year, is $565 billion (1971 dollars). Both of the growth rates are actually averages of two assumed growth rates, one for the 1975 to 1985 period, and a slightly lower rate for the 1985 to 2000 period. Examination of the individual components of GNP shows that most of the GNP difference arises from changes in personal consumption expenditures (see Table B-2). Some additional difference arises from growth in government purchases, which tends to reflect differences in population.

Population increases slightly more in the High Growth Scenario than in the Low Growth Scenario as economic growth was assumed to affect growth in population. The growth rates, an average 0.8 percent per year in the High Growth Scenario and 0.6 percent in the Low Growth Scenario, were selected from a series of U.S. Bureau of the Census projections containing different fertility assumptions.[1] The effect of the differences in rate of increase on projections of population in 2000 is shown in Table B-3. The population projections for 2000 would differ by about 15 million persons, or about 5 percent of the High Growth Scenario population in 2000.

Many of the most interesting shifts in pollutant generation projected by SEAS occur among the Federal Regions. Some portion of these shifts can be attributed to interregional shifts in population. Population is assumed to increase during 1975 to 2000 in both scenarios in all regions, but the portions of the national total represented by each region change to some extent. Primarily the changes

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[1] U.S. Bureau of the Census, Current Population Reports, Series P-25, No. 310, Series 2 and 3, Projections of Total Population, 1977.

TABLE B-1
ECONOMIC GROWTH ASSUMPTIONS

Year	Gross National Product (Billions of 1971 Dollars) High Growth	Gross National Product (Billions of 1971 Dollars) Low Growth
1975	1,141	1,141[a]
1985	1,745	1,531
1990	2,022	1,737
2000	2,734	2,169
Average Annual Growth, Percent, 1975-2000	3.5	2.6

[a] Reconciled with High Growth estimate for 1975.

TABLE B-2
COMPONENTS OF GROSS NATIONAL PRODUCT
(Billions of 1971 Dollars)

		High Growth			Low Growth		
Components of GNP	1975	1985	1990	2000	1985	1990	2000
Personal Consumption Expenditures	745	1,123	1,314	1,847	947	1,078	1,369
Gross Private Domestic Investment	132	276	315	400	265	305	383
Net Exports	14	18	22	24	31	39	56
Government Purchases	251	330	373	463	315	361	330

TABLE B-3
MAJOR DEMOGRAPHIC ASSUMPTIONS

		High Growth			Low Growth		
	1975	1985	1990	2000	1985	1990	2000
Population (millions)	213	234	245	262	228	236	245
Employment (millions)	95	114	119	131	105	110	122
Unemployment Rate (percent)	8.5	4.7	4.7	4.7	5.5	5.0	4.5

reflect an assumed shift in population growth to the Southeast, South Central, and West Regions (Federal Regions IV, VI, and IX). Slight relative declines occur in the fraction of the total represented by the other regions. While these assumed shifts are not extreme, more than one quarter of the 50 million person increase in the High Growth Scenario between 1975 and 2000 occurs in the Southeast Region (Federal Region IV) and an additional 15 percent each occurs in the South Central and West Regions (Federal Regions VI and IX). Table B-4 provides the regional population estimates.

B.1.2 ENERGY SUPPLY AND DEMAND

Total energy supply is assumed to expand at 2.1 percent per year under High Growth conditions and 1.5 percent per year in the Low Growth Scenario. Figure B-1 shows the assumed growth of energy supply and the distribution by energy source for the High and Low Growth Scenarios. In both scenarios, most of the growth in energy supply between 1975 and 2000 would be achieved by burning coal, increasing nuclear electricity generation, and recovering oil from western oil shales. Assumed quantities are presented in Table B-5.

In the High Growth Scenario, coal would expand its share of U.S. energy supply from 22 percent in 1975 to 35 percent in 2000 (growth of 28 quads).[2] Less rapid growth of coal supply is assumed

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[2] Quad = 1 quadrillion Btu. One quad is the energy equivalent of more than 170 million barrels of crude oil, or more than 32 million tons of eastern coal (moisture- and ash-free). Total U.S. energy consumption in 1975 was about 50 quads (about 73 quads input).

TABLE B-4
REGIONAL POPULATION DISTRIBUTION
1975, 1985, and 2000

Federal Region		1975 Population (millions)	High Growth		Low Growth	
			1985 Population (millions)	2000 Population (millions)	1985 Population (millions)	2000 Population (millions)
I.	New England	12	13	14	13	14
II.	New York-New Jersey	25	26	27	26	27
III.	Middle Atlantic	24	26	28	25	27
IV.	Southeast	35	41	48	40	44
V.	Great Lakes	45	48	50	47	49
VI.	South Central	22	25	30	24	27
VII.	Central	11	12	12	12	12
VIII.	Mountain	6	7	8	7	7
IX.	West	25	28	32	28	30
X.	Northwest	7	8	9	8	8
	Total[a]	213	234	262	228	245

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[a] Rounding may create inconsistencies in addition.

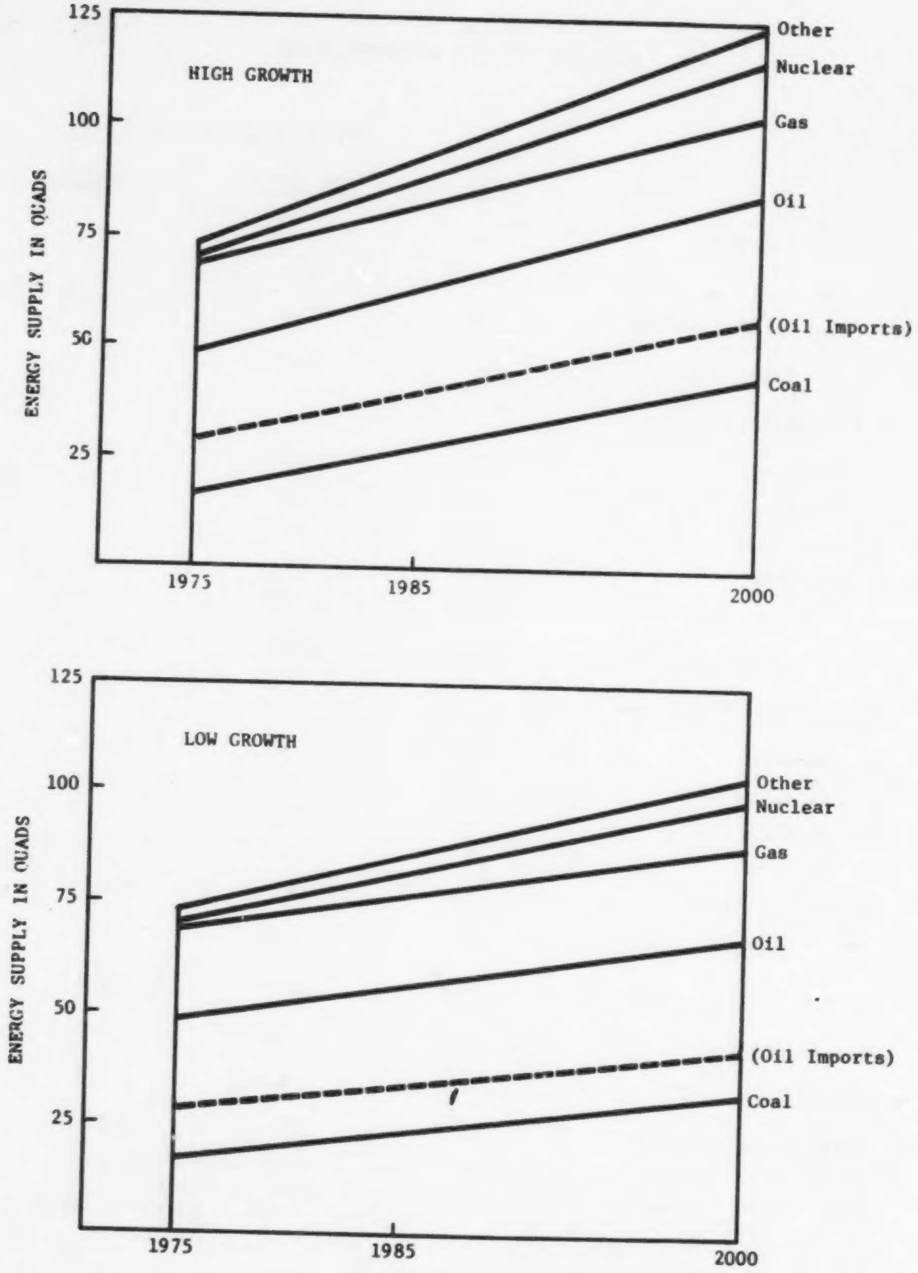

FIGURE B-1
ENERGY SUPPLY ASSUMPTIONS

TABLE B-5
ENERGY SUPPLY ASSUMPTIONS

		Supply in 2000 (10^{15} Btu)	
	1975	High Growth	Low Growth
Coal Production			
Strip mining	8.5	20.7	17.0
Underground mining	7.6	23.3	15.7
Total coal	16.1	44.0	32.7
Oil Production			
Onshore	17.1	13.4	13.4
Offshore	2.8	3.9	4.0
Oil shale	0.0	5.4	2.2
Alaskan	0.4	6.2	6.0
(Oil imports)	(12.7)	(13.2)	(9.4)
Total domestic	20.3	28.9	25.6
Natural Gas Production			
Onshore	14.3	10.8	12.6
Offshore	4.1	3.1	3.2
Alaskan	0.1	2.9	2.2
Biomass	0.0	0.05	0.05
(Gas Imports)	(1.0)	(1.2)	(2.7)
Total domestic	18.5	16.9	18.1
Nuclear[a]	1.8	13.2	10.6
Hydroelectric[a]	2.6	3.2	3.2
Other[b]	0.0	3.8	2.4
Total Energy Supply[c]	73	124	105

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[a] Calculated as electricity demand divided by 0.34, in order to express energy supply on a basis equivalent to fossil fuel supplies. Actual nuclear output is 0.34 times the listed supply estimates.

[b] Supply of fossil fuels displaced by solar, geothermal, and biomass (electric) sources.

[c] Rounding may create inconsistencies in addition.

in the Low Growth Scenario, in which coal production would provide 31 percent of the U.S. energy supply by 2000.

Nuclear energy production is assumed to grow by a factor of seven in the High Growth Scenario and six in the Low Growth Scenario, from 1.8 quads in 1975 to 13.2 quads and 10.6 quads in 2000, respectively.[3] These sharp increases are consistent with actual growth in nuclear production since 1975. In August 1978, net nuclear generating capacity operating in the United States was reported at almost 50,000 megawatts;[4] converted to equivalent input, this represents about 3 quads per year on-line in 1978, which agrees closely with the assumed rates of increase shown in Figure B-1. A total of 9.2 quads of nuclear capacity (input equivalent) was reported to be either operating or under construction in mid-1978.

There is a marked difference between the scenarios on oil imports. In the Low Growth Scenario, the price of crude oil is assumed to rise from a 1975 price of $11.60 per barrel to $59.30 per barrel in 1985 and remain steady thereafter. It is also assumed that this high price will stimulate domestic oil production, and that imports of oil would decrease from 12.7 quads in 1975 to 9.4 quads in 2000.

Oil prices are assumed to rise less, to $39.53 per barrel, by 1985 in the High Growth Scenario. This would have a less restrictive effect on the economy than the higher oil price in the Low Growth Scenario, with the result that consumption of both domestic and imported oil would increase. Specifically, it is assumed that imports would increase from 12.7 quads in 1975 to 13.2 quads in 2000, while domestic production would increase from 20.3 quads to 28.9 quads.

Assumed domestic natural gas production declines in both scenarios, while gas imports increase to compensate. More gas is assumed in the Low Growth Scenario by 2000 than in the High Growth Scenario. Because higher oil prices are assumed, domestic production declines slower in the Low Growth Scenario, from 18.5 quads in 1975 to 18.1 quads in 2000. Gas imports would almost triple over the same period, with a net increase in total gas consumption to 20.8 quads in 2000. In contrast, domestic production is assumed to decline faster in the High Growth Scenario, from 18.5 quads in 1975 to 16.9 quads in 2000. The assumed lower energy prices also would reduce the incentive to import gas supplies, so that total gas consumption in the High Growth Scenario would exhibit a net decline, from 18.5 quads in 1975 to 18.1 quads in 2000.

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[3] Nuclear electricity production is expressed here in terms of equivalent fossil fuel input to obtain the same output. The relationship assumed is Output divided by 0.34 = Input. This relationship is established in order to permit direct measurement of the degree to which nuclear energy displaces other energy supplies.

[4] "World List of Nuclear Power Plants," Nuclear News, Vol. 21, August 1978, pp. 67-85.

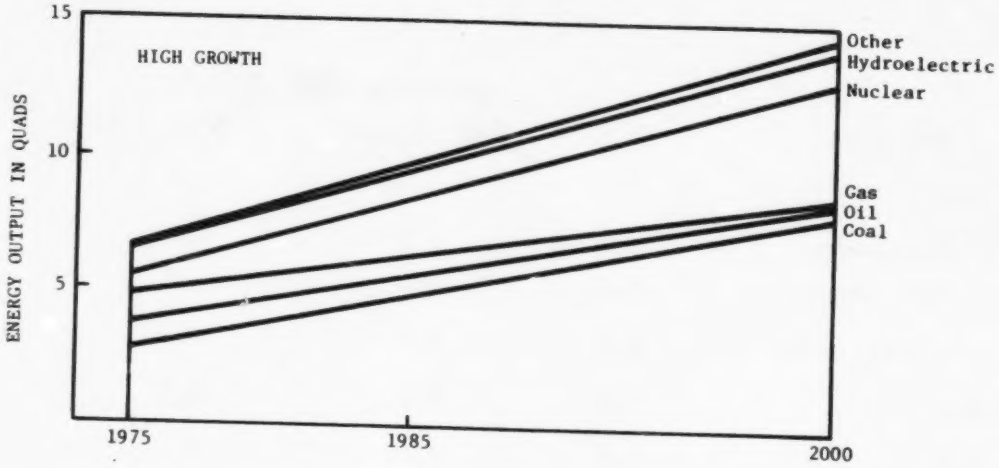
New energy technologies are included in both scenarios. Oil shale production is assumed to increase sharply, especially in the High Growth Scenario, in response to strong petroleum demand. Production would increase from zero in 1975 to 5.4 quads in the High Growth Scenario and 2.2 quads in the Low Growth Scenario by 2000. This assumed difference in oil shale exploitation accounts for almost all of the 3.3 quad difference between scenarios in net domestic oil production in 2000. Other new technologies, such as solar and geothermal, are assumed to displace about 1.2 quads by 2000 in the High Growth Scenario and 0.9 quad in the Low Growth Scenario.

The gross supply of energy in all forms is consumed by five major categories of activities: transportation, residential, commercial, industrial, and exports. Assumptions are made about the demand by each of these categories for coal, oil products, natural gas, electricity, solar, geothermal, and other energy sources.

The electricity consumed by these activities is generated by electric utilities, which convert coal, oil, gas, and other forms of energy to electricity. The total output of electrical energy by the utilities is assumed in the High Growth Scenario to rise from 6.5 quads in 1975 to 14.9 quads in 2000. A similar increase, to 13.3 quads in 2000, is assumed in the Low Growth Scenario.

Figure B-2 and Table B-6 show the assumptions made about the mix of energy sources used to generate this electricity. In both scenarios, almost the entire increase in electrical output is achieved by expanding reliance on coal and nuclear energy. In addition, coal and nuclear energy are assumed to replace oil and gas to varying degrees in electrical generation. This occurs in direct response to legislation prohibiting construction of new oil- and gas-fired electric utilities. Coal and nuclear power are left to provide for almost all growth in electrical output, as well as replacement capacity.

In the High Growth Scenario, the dependence of utilities on coal rises from 44 percent in 1975 to 55 percent in 2000. During the same period, reliance on nuclear generation would rise from 9 percent of the total to 30 percent. Thus, these two sources would provide 85 percent of electrical utility output in 2000. The Low Growth Scenario assumes a similar increase in reliance on coal and nuclear



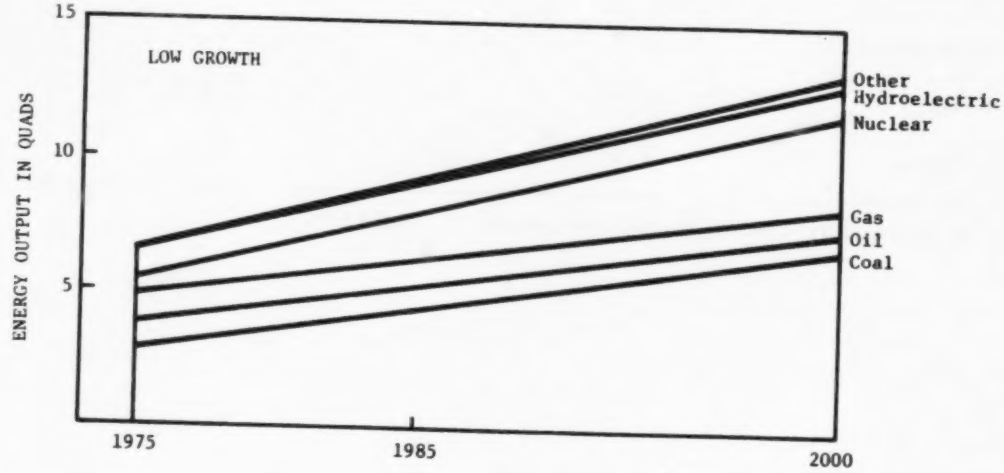


FIGURE B-2
FUEL MIX ASSUMPTIONS FOR ELECTRIC UTILITIES

TABLE B-6
FUEL MIX ASSUMPTIONS FOR ELECTRIC UTILITIES[a]

Fuel Type	1975	Demand in 2000 (10^{15} Btu) High Growth	Demand in 2000 (10^{15} Btu) Low Growth
Coal			
Old plants	2.9	2.3	2.6
New plants	0.0	6.0	4.4
Total Coal	2.9	8.2	6.9
Oil	1.0	0.5	0.8
Gas	1.0	0.05	0.6
Nuclear	0.6	4.5	3.6
Hydroelectric	0.9	1.1	1.1
Other	0.0	0.4	0.3
Total	6.5	14.9	13.3

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[a] Rounding may create inconsistencies in addition.

energy, so that by 2000 coal would provide 52 percent and nuclear energy 27 percent of total electrical generation (together 79 percent).

In both scenarios, reliance of utilities on oil and natural gas is assumed to lessen between 1975 and 2000. This decline is most marked in the High Growth Scenario, in which reliance on oil and natural gas is assumed to fall by 50 percent and 95 percent respectively. The corresponding declines in use of oil and natural gas in the Low Growth Scenario are 20 percent and 40 percent. These declines would occur through substitution of coal and nuclear energy for oil and gas in electrical generation.

The breakdown of final consumption of all forms of energy by transportation, residential, commercial, industrial, and export activities is shown in Table B-7. Overall, the demand for energy by these activities is assumed to increase in the High Growth Scenario by 60 percent between 1975 and 2000, from about 53 quads to 85 quads per year. The corresponding increase in the Low Growth Scenario would be about 33 percent, rising to a 2000 demand of 70 quads.

Several shifts among shares of total energy demand are assumed to occur between 1975 and 2000 (Table B-7). The share of energy demanded by transportation activities is assumed to decline from 34 percent to 27 percent in the High Growth Scenario and 23 percent in the Low Growth Scenario. The actual amount of energy consumed in transportation increases by 26 percent in the High Growth Scenario, but decreases by 11 percent in the Low Growth Scenario.

The share of total energy consumed by transportation declines in response to assumptions about automobile fuel economy and use of mass transit. Automobile gas mileage is assumed to increase from a fleet average of 15.6 miles per gallon in 1975 to 27.5 miles per gallon in 2000. Table B-8 shows the assumed trend in passenger travel toward less reliance on the personal automobile and higher use of bus and rail transit.

Dependence on the automobile is assumed to decline between 1975 and 2000 from 93 percent of passenger miles traveled (PMT) in urban areas[5] to 88 percent in 2000 in the High Growth Scenario. The reduction is much more pronounced under the high oil price assumption of the Low Growth Scenario. In that case, automobile travel would decline to 59 percent of urban PMT. Conversely, dependence on bus and rail transit is assumed to increase more in the Low Growth case.

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[5] "Urban areas" are defined here as areas within Standard Metropolitan Statistical Areas (SMSAs). "Rural areas" lie outside any SMSA.

TABLE B-7
COMPOSITION OF ENERGY DEMAND
1975 and 2000

	1975		2000			
			High Growth Scenario		Low Growth Scenario	
	Demand (10^{15} Btu)	Percent of Total	Demand (10^{15} Btu)	Percent of Total	Demand (10^{15} Btu)	Percent of Total
Transportation	18	34	23	27	16	23
Residential	10	19	12	14	13	18
Commercial	7	14	13	15	11	15
Industrial[a]	16	30	35	42	29	41
Exports	2	3	2	3	2	3
Total[b]	53	100	85	100	70	100

[a] Includes demand for oil and natural gas as chemical feedstocks. See Table B-9 for industrial fuel consumption breakdown.

[b] Rounding may create inconsistencies in addition.

TABLE B-8
PASSENGER TRAVEL BY TYPE
(Percent of Passenger Miles Traveled)

	1975		2000			
			High Growth		Low Growth	
	Urban[a]	Rural	Urban[a]	Rural	Urban[a]	Rural
Auto	93	86	88	80	59	79
Bus	4	2	7	2	24	4
Rail	3	1	5	1	17	4
Air	---	11	---	17	---	14

[a] Areas within Standard Metropolitan Statistical Areas (SMSAs).

Dependence on the automobile remains high in rural settings. It should be noted that the urban and rural shares presented in Table B-8 cannot be compared directly, since air travel is included in the total of rural PMT. If air travel were excluded, rural area dependence on automobiles in 2000 would be 97 percent of passenger miles traveled in the High Growth Scenario, and 91 percent in the Low Growth Scenario. The net result, in any event, is an overall decline in the transportation share of total energy demand in 2000 in both scenarios.

A number of detailed assumptions combine to produce the changes in energy demand by residential and commercial customers evident in Table B-7. In general, increase in demand is stimulated by economic growth. However, this increase would be dampened by the adoption of energy conservation strategies and the replacement of old facilities with more energy-efficient facilities.

The greatest expansion of energy demand is assumed for industrial activities. From 1975 to 2000, industrial demand more than doubles in the High Growth Scenario and nearly doubles in the Low Growth Scenario. The share of total energy demanded by industry rises in both scenarios from 30 percent in 1975 to more than 40 percent of all energy consumption in 2000.

The sources of energy for this expanded consumption are shown in Figure B-3 and Table B-9. Reliance on electricity, oil, and coal increases from 1975 to 2000 at the same time that reliance on natural gas is declining as a percentage of total demand. This is most marked in the High Growth Scenario, where the share of energy obtained from coal rises from 10 percent in 1975 to 25 percent of

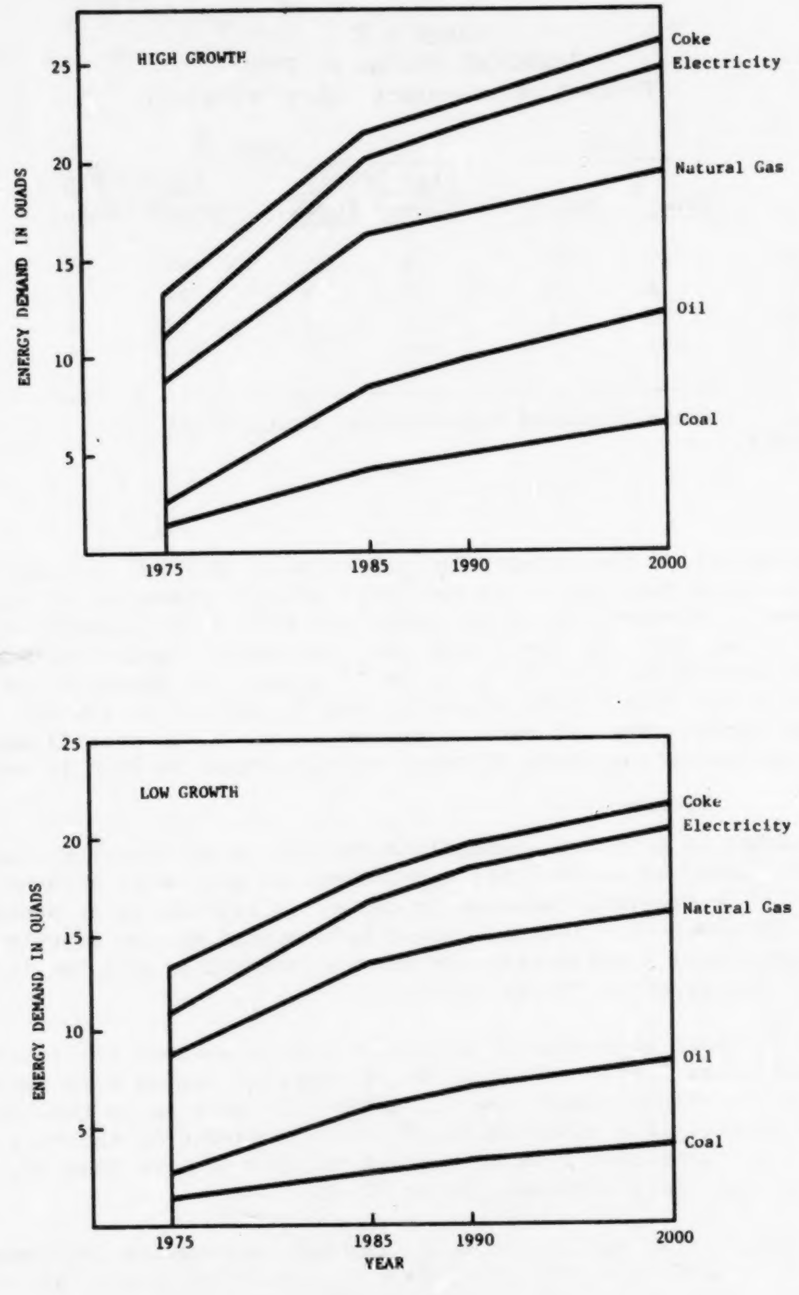

FIGURE B-3
INDUSTRIAL FUEL MIX ASSUMPTIONS

TABLE B-9
MAJOR ASSUMPTIONS ABOUT INDUSTRIAL FUEL CONSUMPTION[a]

Industrial Fuel Consumption (10^{15} Btu)	1975	High Growth 1985	High Growth 1990	High Growth 2000	Low Growth 1985	Low Growth 1990	Low Growth 2000
Coal	1	4	5	7	3	3	4
Oil	1	4	5	6	3	4	4
Natural Gas	6	8	8	7	8	8	8
Electricity	2	4	4	5	3	4	5
Coke	2	1	1	1	1	1	1
Average Retirement Rate for Industrial Facilities (percent)			1.2			1.5	
Level of Incentives for Switching to Coal from Oil or Natural Gas			Moderate[b]			Low	

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[a] Excludes demand for oil and natural gas as chemical feedstocks.

[b] Old facilities are assumed to substitute coal and electricity for oil and natural gas at the rates of 15 percent by 1985 and 30 percent by 2000.

total demand in 2000, while the corresponding share for natural gas declines from 46 percent to 27 percent of the total. In the Low Growth Scenario, the oil and gas shares rise slightly less, and natural gas retains a 35 percent share of industrial energy demand in 2000. The decline in growth of demand beyond 1985, visible in Figure B-3, occurs because of the relatively lower GNP growth rates assumed for that period. The differences between scenarios arise from a combination of differences in growth of total demand, and an assumed higher rate of equipment replacement under the high economic growth condition. Replacement equipment would be subject to Federal requirements to switch from use of oil and gas to coal.

In the High Growth Scenario, direct use of coal would rise by a multiple of nearly 5 by 2000, and at that time would be about 67 percent greater than Low Growth industrial coal demand. In addition, an increasing proportion of the electricity consumed by industry would actually derive from utility combustion of coal (see Figure B-2). Thus both scenarios assume that a large portion of industrial energy demand will be met through direct or indirect use of coal.

The combustion of coal in utility and industrial boilers is one of the major sources of air pollution in the United States. Since pre-1976 boilers are regulated under less stringent regulations (SIPs) than post-1975 boilers (NSPS and BACT), the extent to which coal-fired boilers would contribute to future air pollution largely depends on the rate at which pre-1976 boilers are phased out of operation.

Table B-10 presents a summary of the retirement rates assumed in the High Growth and Low Growth scenarios. These rates represent the

TABLE B-10
PRE-1976 COAL-FIRED BOILER RETIREMENT RATES
(percent/year)

Category	1975-1985	1985-1990	1990-2000	1975-2000
High Growth				
Utility	0.97	0.35	1.05	0.88
Industrial	2.95	3.10	7.13	4.67
Low Growth				
Utility	0.15	0.67	0.72	0.48
Industrial	2.95	3.10	7.13	4.67

average annual decline in: (1) power generation from pre-1976 coal-fired utility boilers or (2) the demand for coal for combustion in pre-1976 coal-fired industrial boilers, as appropriate.

Utility boilers are assumed to be retired more slowly under Low Growth conditions than under High Growth conditions. The rationale for this assumption is that given slower increases in demand for electricity and overall lower economic growth conditions, utilities would attempt to keep older plants on-line rather than retire the plants and build new ones.[6]

In contrast to utility boilers, economic conditions are assumed not to affect the retirement of industrial boilers. These boilers are assumed, in both scenarios, to have a 40-year lifetime. The retirement rates are based on this assumption and on data on boiler age available in the "Major Fuel Burning Installation Data Base."

B.1.3 ENVIRONMENTAL REGULATION

The SEAS model estimates emissions of pollutants by subtracting the amount of pollutant removed from wastestreams from the total amount of pollutant produced by each source. The projected degree of pollutant removal from wastestreams thus is determined by the stringency of environmental controls assumed in the SEAS model. The basic assumption in the model is that sufficient controls will be applied to comply with all applicable regulations.[7]

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[6] This assumption and rationale have been contested in comments on the Environmental Outlook preliminary drafts. Viewed from the opposite perspective the retirement assumptions imply that, given more rapid increases in demands for electricity and higher economic growth conditions, utilities would be expected to retire "old" plants more rapidly, effectively reducing available capacity in the face of increasing demand. Neither of these arguments is all-encompassing or conclusive. However, the results of the air pollutant analysis must be viewed in the light of the assumptions made.

[7] The assumption that regulations will be complied with completely by specific dates is important. Actual emissions of each pollutant could be expected to be somewhat higher than the "net" levels projected by SEAS. The amount by which actual emissions would exceed "net" estimates is a function of compliance. This is discussed for a major pollutants within Chapters 4, 6, and 10.

Information on SEAS environmental regulation assumptions are listed in Table B-11. A brief description of these regulations by medium follows:

B.1.3.1 Air Quality Assumptions

The Clean Air Act (CAA) as amended requires the EPA Administrator to set National Ambient Air Quality Standards (NAAQS). NAAQS consist of primary standards to protect public health, and secondary standards to protect the public welfare, to be met "within a reasonable period of time." EPA has established NAAQS for seven "criteria" pollutants: particulates, sulfur oxides, nitrogen dioxide, hydrocarbons, carbon monoxide, photochemical oxidants, and lead. Each state was required to develop and submit a State Implementation Plan (SIP) to the EPA Administrator. The SIP specifies strategies for achieving the level of air quality established by the NAAQS for individual pollutants in all regions of the state.

EPA has also set New Source Performance Standards (NSPS) for selected industrial categories. These standards are intended to assure that new and replacement equipment will meet uniform high standards of pollution control.

The environmental projections in this report have assumed that SIP and NSPS standards will be met fully by 1985. New steam generators fired by fossil fuels coming on line after 1975 (and before 1984) are assumed to meet the original NSPS standards.[8] The level of pollution control simulated in 1975 is based upon the latest available state-of-compliance data from EPA.

Title II of the Clean Air Act (as amended August 1977) specifies emission limits on mobile sources. These emission limits have been translated into emission factors by EPA's Office of Transportation and Land Use Policy and are incorporated into SEAS.

A nondeterioration standard, known as "prevention of significant deterioration" (PSD), was imposed by the 1977 Amendments to

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[8] In the Clean Air Act Amendments of 1977, Congress mandated revised NSPS regulations by calling for more stringent emissions and rate limits and the use of "Best Available Control Technology" (BACT) on new major emitting facilities. These standards have been simulated for new coal-fired utilities and industrial boilers (1981 and after), although regulations for compliance have not yet been finalized.

TABLE B-11
TIMING AND STRINGENCY OF POLLUTION CONTROL REGULATIONS

Category of Standard	Medium Affected	Applicability	Initially Promulgated Compliance Date[a]	Assumed Compliance Date for Full Enforcement[a]
State Implementation Plans (SIP)	Air	Existing plants; regulations are state-specific.	1975	1985
New Source Performance Standards (NSPS)	Air	New plants; national in scope.	1975	1975
Best Available Control Technology (BACT)	Air	Modified forms of NSPS recommended in the 1977 CAA for boilers and utilities.[b]	1981-boilers 1984-utilities	1981-boilers 1984-utilities
Mobile Source Standards	Air	Phased application to all automobiles, by year of manufacture.[c]	Final CO 1981 Final HC 1980 Final NO_x 1981	Final CO 1981 Final HC 1980 Final NO_x 1981
Best Practicable Technology (BPT)	Water	All plants, national in scope; standards are industry-specific.	1975	1979
Best Available Technology (BAT)	Water	All plants, national in scope; standards are industry-specific.	1983	1985[d]

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[a] Promulgation and enforcement of standards are assumed to be the same for both scenarios.
[b] See also Table A-11.
[c] Phased introduction of standards is to be completed by cited date.
[d] Requirement waived for a number of industries indefinitely; 1984 date met by others; not yet incorporated into data base.

protect existing ambient air quality. Class I areas, considered to be very clean, are permitted little or no increase in ambient pollutant concentrations. Class II areas are allowed moderate increases in air pollution; and Class III areas, which are relatively dirty, are allowed more intensive growth, permitting levels of air quality deterioration up to ambient air quality standards.

States with "non-attainment areas" (areas that do not meet ambient standards) are required by the 1977 Amendments to revise their SIP standards by June 30, 1979, and apply an "offset" policy to new sources. This offset policy specifies that, if a new facility is being added in the area, air pollution from existing sources must be reduced by more than the amount that would be added by the new facility in the area, even if the facility itself would be in compliance with New Source Performance Standards. The offset policy also applies to major modifications or expansions of existing plants.

The existence of PSD and non-attainment areas is recognized only indirectly in SEAS. The method used by SEAS to choose locations for future power plants and coal conversion facilities avoids siting facilities where they would conflict with PSD and non-attainment regulations. No attempt has been made to model offset policies or revised SIPs.

B.1.3.2 Water Quality Assumptions

The Federal Water Pollution Control Act (FWPCA) Amendments of 1972 provide the legislative basis for the water quality regulations and assumptions discussed in this report. The Clean Water Act (CWA) of 1977 amends the FWPCA's funding of treatment works and compliance dates.

The FWPCA established several national goals related to water quality:

- Elimination of polluting discharges to the nation's waters by 1985
- Prohibition of toxic pollutant releases
- Areawide waste treatment planning

The Act further established an interim water quality goal that will protect fish, shellfish, and wildlife and will provide for recreation, wherever attainable, by July 2, 1983.

To attain the interim goal, FWPCA required EPA to set point source effluent limitations in two stages. The first stage established effluent limitations to be met by July 1, 1977, based on the

Best Practicable Control Technology (BPT) then available. For publicly owned waste treatment works this technology is defined as secondary treatment; for industrial treatment, each industry has a standard for pollutant discharge per unit of production. The second stage develops standards based on the Best Available Technology (BAT) economically achievable by July 1983. For publicly owned waste treatment plants, this may imply tertiary treatment. The SEAS scenarios developed for this study include the assumption that BPT standards will be met in 1979 and BAT by 1985.

B.1.3.3 Solid and Hazardous Waste Assumptions

New regulations of potentially great importance are being developed under provisions of the Resource Conservation and Recovery Act of 1976 (PL 94-580) (RCRA). These regulations are intended to promote solid waste management planning, prohibit open dumping, regulate hazardous wastes, and promote advanced recycling systems. RCRA regulations are not yet available for inclusion in the SEAS model. Some industrial and economic implications of the Act are discussed in Chapter 10 on the basis of the most recent information available about the emerging regulations.

B.1.3.4 Toxic Substances Assumptions

The Toxic Substances Control Act of 1976 (PL 94-469) (TSCA) gave EPA broad discretionary authority to control dangerous chemical substances. Major provisions of the Act require manufacturers and processors of potentially harmful chemical substances and mixtures to test those substances to determine their effect on health and the environment. The Act also requires that manufacturers who plan to produce new chemical substances or to produce existing chemicals for significant new uses must notify EPA in advance of production.

Regulations published so far under TSCA provisions include: a requirement to submit health and environmental studies for ten groups of chemical substances; disposal and marking requirements for polychlorinated biphenyls; and regulation of the manufacture, processing, and distribution of fluorocarbons. Regulations that would ban the manufacture, processing, distribution, and use of polychlorinated biphenyls have been proposed.

The only regulations that affect specific chemicals were promulgated in February and March 1979. These regulations could not readily be included in the SEAS model at that time, and therefore are not part of the model's data base. However, their implications were considered to the extent possible in Chapter 11.

APPENDIX C
SELECTED ENGLISH-METRIC CONVERSION FACTORS

To convert from	To	Multiply by
Acres	Hectares	0.40468564
	Square feet	43560
	Square kilometers	0.0040468564
	Square meters	4046.8564
	Square miles	0.0015625
Atmospheres	Bars	1.01325
	Inches of Hg (32°F)	29.9213
	Kilograms/square centimeter	1.03323
	Millimeters of Hg (0°C)	760
	Newtons/square meter	101320
	Pounds/square inch	14.6960
Barrels (petroleum, U.S.)	Cubic feet	5.614583
	Cubic meters	0.15898
	Gallons (U.S.)	42
	Liters	158.98284
Bars	Atmospheres	0.986923
	Inches of Hg (32°F)	29.5300
	Kilograms/square centimeter	1.019716
	Newtons/square meter	100,000
	Pounds/square inch	14.5038
Btu	Btu (IST)[a]	0.999346
	Calories, gram (IST)	251.831
	Foot-pounds	777.649
	Horsepower-hours	0.000392752
	Joules	1054.35
	Joules (international)	1054.18
	Kilowatt-hours	0.000292875
	Kilowatt-hours (international)	0.000292827
Feet	Centimeters	30.48
	Inches	12
	Meters	0.3048
	Microns	304800
	Miles (statute)	0.000189393
Gallons (liquid, U.S.)	Barrels (liquid, U.S.)	0.031746032
	Barrels (petroleum, U.S.)	0.023809524
	Cubic centimeters	3785.4118
	Cubic feet	0.133680555

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SELECTED ENGLIGH-METRIC CONVERSION FACTORS (CONTINUED)

To convert from	To	Multiply by
	Cubic inches	231
	Cubic meters	0.0037854118
	Liters	3.785306
	Tons (long, petroleum)	0.00319
	Tons (metric, petroleum)	0.00325
	Tons (short, petroleum)	0.00358
Inches of Hg (32°F)	Atmospheres	0.0334211
	Bars	0.0338639
	Kilograms/square meter	345.316
	Millimeters of Hg (60°C)	25.4
	Newtons/square meter	3386.5
	Pounds/square inch	0.49115
Miles (statute)	Feet	5280
	Kilometers	1.609344
	Meters	1609.344
Pounds (avoirdupois)	Grams	453.59237
	Kilograms	0.45359237
	Ounces (avoirdupois)	16
	Tons (long)	0.00044642857
	Tons (metric)	0.00045359237
	Tons (short)	0.0005
Pounds/square inch	Atmospheres	0.0680460
	Bars	0.0689476
	Inches of Hg (32°F)	2.03602
	Kilograms/square centimeter	0.070306958
	Millimeters of Hg (0°C)	51.7149
	Newtons/square meter	6894.9
Tons (long)	Barrels (petroleum, U.S.)	7.45
	Kilograms	1016.0469
	Pounds (avoirdupois)	2240
	Tons (metric)	1.0160469
	Tons (short)	1.12
Tons (metric)	Barrels (petroleum, U.S.)	7.33
	Kilograms	1000
	Pounds (avoirdupois)	2204.6226
	Tons (long)	0.98420653
	Tons (short)	1.1023113

SELECTED ENGLISH-METRIC CONVERSION FACTORS (CONCLUDED)

To convert from	To	Multiply by
Tons (short)	Barrels (petroleum, U.S.)	6.65
	Kilograms	907.18474
	Pounds (avoirdupois)	2000
	Tons (long)	0.89285714
	Tons (metric)	0.90718474

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[a] IST - International Steam Table.

Source: Adapted from Tetra Tech, Inc., Department of the Navy Energy Fact Book, 1979, pp. B-3 - B-7.

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